SCRAP TIRE WORKSHOP

CONSTRUCTION APPLICATIONS FOR LANDFILLS

Training Manual/Reference Guide

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Funded and Sponsored by:

DNR

Iowa Department of Natural Resources

June 22, 2005

Scrap Tire Workshop: Construction Applications for Landfills

Table of Contents

SECTION 1

Introduction………………………………………………………………………….. 1

Figure 1: Iowa End Users of Processed Tires……………………………… 1

Civil Engineering Applications…………………………………………………. 3

Definitions: Baled Tire…………………………………………………….. 5

Crumb Rubber…………………………………………………. 5

Cut Tire………………………………………………………….. 5

Processed Tire………………………………………………… 5

Tire Derived Aggregates (TDA).……………………………… 5

Used Tire……………………………………………………… 5

Waste Tire……………………………………………………… 5

SECTION 2

ASTM International Standard………………………………………………… 7

Scope of ASTM……………………………………………………………… 7

Use of ASTM………………………………………………………………… 7

ASTM Material Characterization for Tires…………………………………. 8

Class I Fills…………………………………………………… 8

Class II Fills………………………………………………… 8

ASTM Leachate Research……………………………………………….. 9

Figure 2: Leaching From Tires……………………………….. 9

Water Table Considerations…………………………………. 9

Research Highlight: Leaching From Tires…………………… 10

SECTION 3

General Physical Characteristics of Tire Derived Aggregate (TDA)…..……………. 11

Compacted Dry Density…………………………………………………... 11

Thermal Conductivity…………………………………………………………… 11

Hydraulic Conductivity…………………………………………………………. 11

Table 1: Hydraulic Conductivity of Different Sized Tire Shreds…………………………………………………….. 13

Specific Gravity……………………………………………………………….. 14

Table 2: Unit Weight of Different Sized Tire Shreds……….. 15

Compressibility……………………………………………………………….. 16

Table 3: Compressibility of Tire Derived Aggregates………. 16

Figure 3: Tire Shred Compressibility………………………….. 17

Table 4: Compressibility of Different Sized Tire Shreds……. 18

Shear Strength………………………………………………………………… 19

Table 5: Shear Strength of Different Sized Tire Shreds……. 20

Water Absorption…………………………………………………………….. 21

Combustibility………………………………………………………………….. 21

Case Study on Combustibility…………………………………. 23

SECTION 4

Other Issues of Note…………………………………………………………… 25

Compatibility with Geosynthetics and Liners……………………................. 25

Exposed Wires……………………………………………………………….. 26

Worker Safety…………………………………………………………………. 27

Uniformity and Quality of Product……………………………………………. 27

Tire Derived Aggregate Quality Concerns…………………………………… 27

Proper Storage of Stockpiled Material………………………………………… 28

Criteria for Temporary Storage of Tire Chips………………………… 28

Other TDA Storage Tips……………………………………………….... 29

SECTION 5

Engineered Landfill Applications for Scrap Tires…………………………………… 31

Leachate Collection……………………………………………………………….. 31

Table 6: Scrap Tire Yield…………………………………………………… 33

Table 7: Type A Drainage and Insulating Media…………………….. 35

Leachate Case Study: Blackhawk County Landfill………..………… 37
Leachate Collection Layer

Leachate Case Study: Metro Park East Landfill……………….……… 38
Leachate Recirculation Trench

Leachate Case Study: Audubon County Sanitary Landfill…………. 40
Recirculation Trench

Leachate Case Study: Des Moines County Regional Sanitary
Landfill - Leachate Toe Drain …………..….. 42

Leachate Case Study: Michigan State University……….………….. 44
Leachate Recirculation Blanket

Landfill Gas Collection Layer………………………………………………… 45

Figure 3: Landfill Gas Collection Cycle……………………………… 45

Table 8: Tire Derived Aggregate Size (Landfill Gas Layer)……… 48

Landfill Gas Control Trench…………………………………………………… 51

Landfill Operations Layer.…………………………………………………… 55

Table 9: Tire Derived Aggregate Size (Operations Layer)………….. 57

Roadbase………………………………………………………………………… 59

Study Highlight: Maine Local Roads Center and the New England
Transportation Center…………………………..……...62

Study Highlight: Mille Lacs County, MN………..……………………..63

Study Highlight: Metro Park East Landfill, Mitchellville, IA…………..63

SECTION 6

State and Local Approval Processes…………………………………………………. 65

State Code: IAC Chapter 117……………………………………………… 65

Whole Tire Usage…………………………………………………………. 65

Approved End Uses of Whole Tires…………………………………. 65

Required Notifications and Approval for Whole Tire Uses…………. 65

Beneficial Reuse Criteria for Whole Tires...................................... 66

Shredded Tires……………………………………………………………. 66

Approved End Uses of Shredded Tires……………………………. 66

Required Notifications and Approval for Shredded Tires…………. 67

Cut Tires………………………………………………………………….... 68

Approved End Uses of Cut Tires……………………………………. 68

Beneficial Use Criteria of Cut Tires……………………………….... 68

Required Notifications and Approval for Cut Tires………………….. 68

Other Beneficial Reuses of Tires………………………………………….... 68

Beneficial Reuse Denials………………………………………………… 69

Compliance with Local, State, and Federal Regulations…………………... 69

Tips for Submitting a Permit Amendment for a Tire Use Project………….. 70

SECTION 7

Iowa Administrative Code 567-117……………………………………. Appendix A

Sample Specifications for Landfill Engineering Applications………… Appendix B

Sources of Tire Derived Aggregate……………………………………... Appendix C

Case Study Supplements…………………………………………….... Appendix D

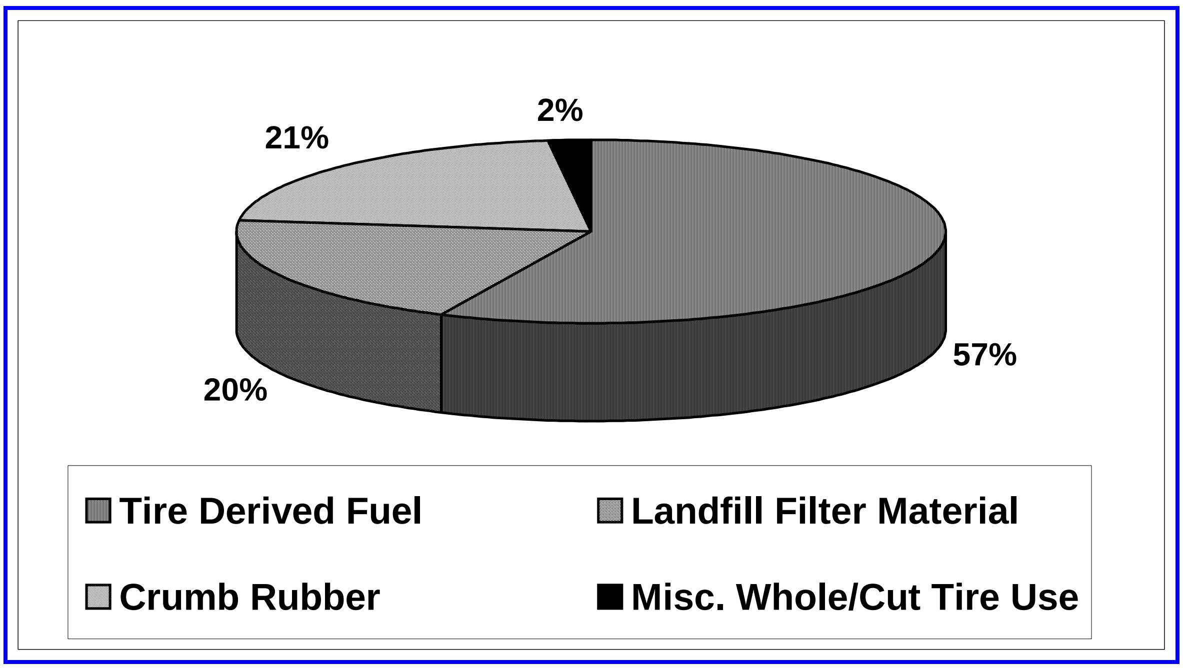
Works Cited and Additional Resources List…………………………… Appendix E

SECTION 1: Introduction

Iowans generate over 3 million scrap tires each year – an average of nearly one scrap tire per person in the state. In 2003, Iowa tire recyclers processed more than 5 million tires, including tires collected from out-of-state. Iowa-based end-users absorbed more than 3.5 million waste tires.

Markets for used tires in Iowa include the use of Tire Derived Fuel (TDF), manufacture of poured-in-place athletic track surfaces, turf amendment materials, roofing products, shingles, playground surfacing, and other products made from processed tires that are molded or extruded into value added products. Figure 1: **Iowa End Uses of Processed Tires** presents a breakdown of how processed tires are being utilized in Iowa.

Figure 1: Iowa End Uses of Processed Tires



Source: Iowa DNR

Expanding the use of scrap tires through existing applications and uncovering new uses are key to maintaining and growing markets for ever expanding tire generation rates.

One often overlooked and underutilized market for scrap tires is for civil engineering applications.

Scrap tire use in civil engineering applications has undergone a series of ups and downs since their first serious use in the early 1990's. The promise of providing a value added end use for the multitudes of used tire piles across the country was quickly dissipated by exothermic project fires and a general lack of knowledge regarding the engineering properties of tires. Projects were introduced largely as “experimental” or as “demonstrations” and in most areas were not widely duplicated.

In 2005, the situation is quite different. New information on engineering properties of tires, backed by successful engineering applications and the development of American Society of Testing Materials (ASTM) construction standards, provides data that should answer the doubts, concerns, and uncertainties that previously limited the expansion of markets for scrap tires in civil engineering projects.

Typical Recycled Tire End-Products

Source: Iowa DNR

<u>Civil Engineering Application</u>:

To be considered a civil engineering application (and not a disposal application) a project should reuse waste tires, either whole or processed, in place of naturally occurring materials in construction (i.e. sand, gravel, clay), in a manner that provides a defined engineering benefit.

Civil engineering applications should not be used to just bury tires! Civil engineering projects utilizing tires are best characterized by producing cost effective engineering benefits.

Staging tire chips for a leachate collection layer at Scott Area Sanitary Landfill, Buffalo, IA
Source: Scott Area Solid Waste Management Commission and Foth and Van Dyke

Engineering applications for scrap tires have experienced excellent success in Municipal Solid Waste (MSW) landfill situations. Numerous civil engineering applications have used scrap tires for landfill projects that include leachate collection and redistribution layers, gas collection layers, and landfill roads.

Scrap tire derived aggregates (TDA) that are most commonly utilized in engineered landfill projects are characterized as being:

- Lightweight;
- Durable;
- Compressible;
- Good insulators, and:
- Having good hydraulic conductivity.

As the state of Iowa implements federal regulations requiring Iowa landfills to operate over Subtitle D liners, landfills are in an excellent position to examine the potential use of scrap tires for new construction projects.

In examining prior research conducted on utilizing TDA for various engineering applications, it was found that other than ASTM guidelines, there appears to be no industry-wide standards that have been readily adapted by regulatory authorities across the country.

Each engineering application has unique intrinsic characteristics that require adjustments and variances to provide optimal performance. For example, two seemingly similar landfill leachate projects may require widely different engineering plans for using TDA based on soil conditions, type of liner used (clay vs. plastic), and amount of overlying waste.

Additionally, recommended factors including optimal number of compaction passes, optimal TDA size, and optimal layer thickness have slight variances from information source to information source. These variations seem to be related to subtle deviations in research findings, individual interpretations of these findings, and ultimately, subtle differences in guidelines adopted and provided by regulatory bodies.

Use of sound engineering principles and design concepts, in union with proven research results, may result in the best use of TDA in Iowa landfill applications.

Ultimately, as stated in ASTM Standard D 6270:

It is the responsibility of the design engineer to determine the appropriateness of using scrap tires in any particular application and to select applicable tests and specifications to facilitate construction and environmental protection. (4)

Definitions:*

*Obtained from Iowa Administrative Code IAC 567-117

Baled Tire:* A method of volume reduction of waste tires, whereby whole or cut tires are compacted into a bundle and then banded together to form a tire bale. Baled tires shall not be considered processed tires and shall be defined as solid waste, unless the bales are incorporated into an approved beneficial use project.

Crumb Rubber:* A material derived by reducing waste tires or other rubber into uniform granules of 3/8 inch or less with the inherent reinforcing materials such as steel and fiber removed along with other contaminants.

Cut Tire:* A waste tire from which the tire face, tread, or sidewall has been cut or removed for beneficial use. A cut tire shall consist of pieces greater than 18 inches on any one side.

Processed Tire:* A tire that has been processed through grinding, shredding, or other means, thereby producing a material that is readily suitable for marketing into product manufacturing, energy recovery, or other beneficial reuse markets. Waste tires that have been compacted, baled, cut, or shredded without a suitable market shall not be considered processed tires and shall be regulated as solid waste.

Tire Derived Aggregates (TDA): Pieces of processed tires that have a consistent shape and are generally between 25mm (1 in.) and 300mm (12 in.) in size.

Used Tire:* A tire that previously has been on a vehicle but that retains suitable tread depth and is free of damage or defects so that it may be safely returned to its original purpose.

Waste Tire:* A tire that is no longer suitable for its originally intended purpose due to wear, damage, or defect. This definition shall include a tire mounted on a rim, but not on a vehicle. “Waste tire” does not include a non-pneumatic tire.

Typical Tire Processing Operation
Source: Iowa DNR

SECTION 2: ASTM International Standard

In the late 1990's, in response to the growing interest in engineering applications for tire derived aggregates (TDA), the American Society for Testing Materials (ASTM), now known as ASTM International, developed a set of guidance standards for proper specification of TDA in civil engineering projects.

In 1998, the guidance document titled: *ASTM D 6270, Standard Practice for Use of Scrap Tires in Civil Engineering Applications* was developed to help standardize the test methods and terms relating to the testing of waste tire derived products used in civil engineering designs. These standards were reapproved by ASTM in 2004.

ASTM D 6270 can be ordered through the ASTM web site at: http://www.astm.org.

Scope of ASTM D 6270

- Provides guidance for testing the physical properties of scrap tire materials.
- Gives data for assessment of the leachate generation potential of processed or whole scrap tires in lieu of conventional civil engineering materials, such as stone, gravel, soil, sand, or other fill materials.
- Outlines typical construction practices.

Use of ASTM D 6270

ASTM D 6270 is intended to encourage wider utilization of scrap tires in civil engineering applications.

It is the responsibility of the design engineer to determine the appropriateness of using scrap tires in any particular application and to select applicable tests and specifications to facilitate construction and environmental protection. (4)

ASTM Material Characterization for Tires

In an effort to reduce the possibility for TDA internal heating reactions after installation, ASTM has developed ASTM D 6270 in a manner that helps reduce the factors that could create conditions favorable for this reaction.

Below, ASTM characterizes TDA into two major classifications; Class I Fills and Class II Fills. (4)

Class I Fills: (TDA placed in layers less than 1m (~3') thick.)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.
- No special design features required to reduce heating situations.

Class I Fills are typically utilized in landfill leachate and gas control applications.

Class II Fills: (TDA placed in layers ranging from 1m (~3') to 3m (~10') thick.)

- Have a maximum of 25% (by weight) passing the 38 mm (1.5") sieve.
- Have a maximum of 1% (by weight) passing the 4.75 mm (~.19") sieve.
- Free from fragments of wood, wood chips, and other fibrous organic matter.
- Less than 1% (by weight) of metal fragments not at least partially encased in rubber.
- Metal fragments partially encased in rubber shall protrude no more than 25 mm (~1") from the cut edge of the TDA on 75% of the pieces and no more than 50 mm (~2") on 100% of the pieces.
- Projects should be constructed in a way that reduces infiltration of water and air.
- No direct contact between TDA and soil containing organic material (i.e. topsoil).
- Drainage features located at the bottom of the fill that could provide free access to air should be avoided.

Class II fills are typically used as infill or as road base subgrade where deeper fill depths are required.

ASTM Leachate Research

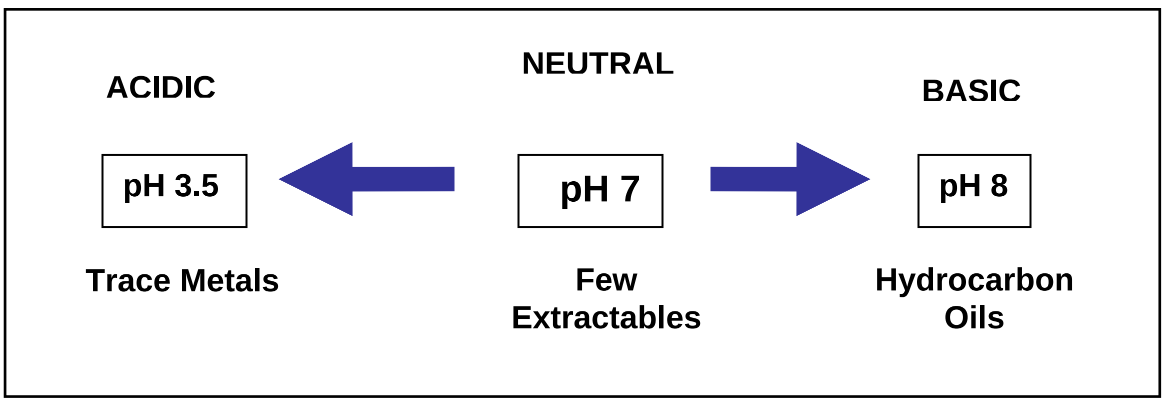
The Toxicity Characteristics Leaching Procedure (TCLP) was used by ASTM International to determine if TDA is a hazardous waste.

For all regulated metals and organics, the results for TDA are well below the TCLP regulatory limits; therefore, TDA is not classified as a hazardous waste (*at the federal level via 40 CFR*). (4)

ASTM D 6270 suggests *that it is preferable to use TDA in environments with a near neutral pH to reduce leaching of metals (in areas of low pH) and leaching of organics (in areas of high pH).* (4)

Figure 2: **Leaching From Tires**, provides a summary of leaching concerns from tires in different types of soils.

Figure 2: Leaching From Tires



Water Table Considerations

1. TDA placed below the water table can have manganese and iron releases that are significantly above their secondary drinking water standards (4).

2. According to ASTM International, TDA placed below the water table level leaches low levels of organic compounds and further study is needed to determine if levels are high enough to be of concern. (4)

At this time, <u>ASTM</u> <u>does not</u> recommend the use of tire derived aggregates <u>below the water table</u>.

Research Highlight*

A five year study conducted from 1993 through 1997 by Dana M. Humphrey, Ph.D., P.E. (University of Maine) and Lynn E. Katz Ph.D. (University of Texas at Austin) concluded:

- TDA has a negligible effect on the concentration of metals with primary (health based) drinking water standards.
- TDA can have an impact on secondary (aesthetic based) drinking water standards for concentrations of iron (Fe), manganese (Mn), and zinc (Zn) in the immediate area of placement. However, in the study virtually all samples taken down gradient from installation points were found to contain only trace concentrations of these three metals.
- TDA placed below the water table appears to have a negligible off-site effect on water quality.

* Information obtained from Reference #19

While it is technically feasible to utilize TDA in storm and groundwater drainage situations, design engineers should take into consideration site specific conditions (i.e. soil pH and proximity of drinking water sources) when considering a final design.

SECTION 3: General Physical Characteristics of Tire Derived Aggregate (TDA)

Definition: <u>Compacted Dry Density</u>

A measure of the compactive effort required to achieve a workable material density.

The compacted dry density of TDA makes it an attractive light weight fill for embankment construction on weak compressible soils where slope stability or excessive settlement is a concern.

The average compacted density of TDA ranges from 40 lb/ft^3 to 52 lb/ft^3 (1/3 to 1/2 that of typical soil). (4) (5) (6) These densities are typically achieved through 4-8 passes from a sheepsfoot, landfill compactor, tracked bulldozer, smooth drum roller, or equivalent equipment.

Loosely dumped TDA typically exhibits a dry density between 21 lb/ft^3 and 31 lb/ft^3. (2)

Typical loose dry densities of 3" to 4" nominal TDA in Iowa have been reported to be between 24 lb/ft^3 and 28 lb/ft^3. (24)

Lab testing has indicated that higher compacted densities are achieved when TDA is mixed with soils. (2)

Definition: <u>Thermal Conductivity</u>

Relates to the ability of a material to conduct heat.

The thermal conductivity of TDA makes it a good option for applications where insulation value is important. (i.e. Protecting roads from freeze/thaw cycles).

- **TDA has a thermal conductivity of 0.1 to 0.2 Btu/hr-ft-E F** (approximately eight (8) times lower than for typical granular soils). (6)
- TDA has been shown to reduce frost penetration by up to 25%. (6)

Definition: <u>Hydraulic Conductivity</u>

The rate of water flow under laminar flow conditions through a unit cross-sectional area of porous medium under unity hydraulic gradient and standard temperature conditions.

The hydraulic conductivity of TDA is of primary importance when assessing the feasibility of using TDA as a drainage material.

TDA hydraulic conductivity has been measured in a range from 0.0005 to 59.3 cm/sec. (1.42 to 168,094 ft/day). (1) This wide range of hydraulic conductivity values may be attributed to differences in shred size, composition, compaction level, and other study specific testing variables.

A study conducted by Shive-Hattery Engineers and Architects, Inc. (West Des Moines, IA) for the Iowa Department of Natural Resources in 1990, concluded that TDA had a hydraulic conductivity averaging between .79 to 2.74 cm/sec. (2,239 to 7,767 ft/day) The study conducted seven trial tests utilizing a 1.5" TDA (2.07 cm/sec or 5,868 ft/day average coefficient of permeability) and five trial tests utilizing a .75" TDA (1.93 cm/sec or 5,471 ft/day average coefficient of permeability). (18)

A report by GeoSyntec Consultants, Inc. for the California Integrated Waste Management Board stated that the lower range of hydraulic conductivity is generally associated with tests conducted on smaller tire shreds under high vertical stress. (11)

Table 1: **Hydraulic Conductivity of Different Size Tire Shreds** was assembled by Reddy and Marella and shows relations between TDA size and hydraulic conductivity determined from prior research studies. (1)

Table 1: Hydraulic Conductivity of Different Size Tire Shreds*

Reference	Tire Shred Size (inch)	Hydraulic Conductivity (cm/s)	Specific Test Conditions
Bressette, 1984, ASTM 1998	1-2.5	2.9-23.5	-
	0.2-2.0	3.8-59.3	-
Hall, 1991	1.5	1.43-2.64	Simulated overburden of 0 to 35 feet of MSW
	0.75	0.79-2.74	Simulated overburden of 0 to 25 feet of MSW
Humphrey et al, 1992, Humphrey and Sandford, 1993, ASTM, 1998	0.4-2	7.7	Void ratio = 0.925
	0.4-2	2.1	Void ratio = 0.488
	0.75-3	15.4	Void ratio = 1.114
	0.75-3	4.8	Void ratio = 0.583
	.04-1.5	6.9	Void ratio = 0.833
	.04-1.5	1.5	Void ratio = 0.414
Edil et al., 1992, Edil and Bosscher, 1994	2-3	0.6	Stress (psf): 0
		0.45	1440 psf
		0.4	2881 psf
Ahmed and Lovell, 1993	0.5-1.5	0.58	-
Duffy, 1995	2	0.7	2500 psf (40 feet MSW)
		0.53	5000 psf (80 feet MSW)
		0.25	10000 psf (160 feet MSW)
		0.12	15000 psf (240 feet MSW)
Narejo and Shettima, 1995	2.4-4.0	55	1879 psf
		20	3132 psf
		10	7308 psf
		6	11484 psf
Andrews and Guay, 1996	1-2	1	-
Masad et al., 1996	0.18	0.002	3132 psf
		$5x10^{-4}$	7308 psf
Cecich et al., 1996	0.2-0.6	0.03	ASTM D2434
Bernal et al., 1996	2	1.2	-
Zimmerman, 1997	8-16	9	Void ratio = 2.77
		3.2	Void ratio = 1.53
		1.8	Void ratio = 0.78
Lawrence et al., 1998	0.5-1.5	7.6	Void ratio = 0.693
	0.5-1.5	1.5	Void ratio = 0.328
	0.5-3	16.3	Void ratio = 0.857
	0.5-3	5.6	Void ratio = 0.546
Chu, 1998	0.25-0.5	0.16	-
	0.5-1.0	0.18	-
	1.0-1.5	0.18	-
Reddy and Saichek, 1998	0.5-5.5	0.65	3400 psf, Compression - 50%
	0.5-5.5	0.01	21000 psf, Compression - 65%

*Table obtained from Reference #1

Hydraulic conductivity decreases significantly as the percentage of soil in TDA increases. For mixtures of TDA and soil, with 30% to 50% soil by weight, hydraulic conductivities approach those of the soil itself. (2)

TDA produced for civil engineering applications (greater than 2") generally has a hydraulic conductivity of greater than 1 cm/s (118 feet/day), making it suitable for many drainage applications, including French Drains, drainage layers in landfill liner and cover systems, and leach fields for on-site sewage disposal systems. (4)

Definition: <u>Specific Gravity</u>

Specific gravity is the ratio of the unit weight of solids divided by the unit weight of water. A material, whose unit weight of solids equals the unit weight of water, has a specific gravity of 1.0.

The apparent specific gravity of TDA generally ranges from 1.02 to 1.27 depending on the amount of steel wire in the tire. (2)

The value of TDA as lightweight fill stems from its low specific gravity, which is less than one-half of the value for common earthen coarse aggregate (typically 2.6 to 2.8). (11)

Table 2: **Unit Weight of Different Size Tire Shreds,** was assembled by Reddy and Marella and shows research conducted on TDA specific gravity. (1)

Table 2: Unit Weight of Different Size Tire Shreds*

Reference	Tire Shred Size (inch)	Dry Unit Weight (pcf)	Specific Test Conditions
Bressette, 1884, ASTM, 1998	0.2-2.5	25-38	-
Humphrey et al., 1992, Humphrey and Manion, 1992, Manion and Humphrey, 1992, Humphrey and Sandford, 1993, ASTM, 1998	0.08-3	21.4	No compaction
	0.08-2	25.5-30.3	
	0.08-1	31.1	
Ahmed, 1993, Ahmed and Lovell, 1993, ASTM, 1998	0.5-2	29.3	No compaction
	0.5-1	30.8	No compaction
	0.5-1	31.2	ASTM D 4253
	0.5	29.7	ASTM D 4253
	0.5-2	38.6	50% standard - compaction energy
	0.5-1	40	
Humphrey et al., 1992, Humphrey and Manion, 1992, Manion and Humphrey, 1992, Humphrey and Sandford, 1993, ASTM, 1998	0.08-3	39	60% standard - compaction energy
	0.08-2	39.3-40.4	
	0.08-1	15.3	
Ahmed, 1993, Ahmed and Lovell, 1993, ASTM, 1998	0.4-2	40	Standard - compaction energy
	0.5-1.5	40.6	
	0.5-1	41	
	0.5	39.8	
Edil and Bosscher, 1992, Edil and Bosscher, 1994, ASTM, 1998	0.75-3	37	6 inch-diameter mold compacted by 10 lb-rammer falling 12 inches
	0.75-3	35	12 inch-diameter mold compacted by 60 lb-rammer falling 18 inches
Humphrey and Manion, 1992, Manion and Humphrey, 1992, ASTM, 1998	0.08-2	41.5	Modified - compaction energy
Ahmed, 1993, Ahmed and Lovell, 1993, ASTM, 1998	0.5-2	41.7	
	0.5-1	42.7	
Upton and Machan, 1993	2	24-33	Loose
		45	Compacted
		52-53	Surcharged with 3 feet soil, pavement and highway traffic
Newcomb and Drescher, 1994	0.78-1.8	31.2-35.2	
Black and Shakoor, 1994	<0.04-0.27	33	-
Duffy, 1995	2	30-50	-
Masad et al., 1996	0.18	39.4	
Cecich et al., 1996	0.2-0.6	35.1-37.3	ASTM D1557
Andrews and Guay, 1996	1-2	40	-
Wu et al., 1998	<0.08	33.3	Tested tire shreds without steel in them
	<0.37	31.5-37.5	
	<0.74	35.8	
	<1.5	37.4	
Tweedie et al., 1998	1.5	44.3	Full scale field tests
	3	43.1	
Chu, 1998	0.25-1.5	43.2-43.6	-
Reddy and Saichek, 1998	0.5-5.5	26	No compaction

*Table obtained from Reference #1

Definition: <u>Compressibility</u>

The susceptibility of a material to volume change due to changes in stress.

Due to its porosity and high rubber content, TDA is highly compressible under loaded conditions. Under high normal loads, TDA can compress by as much as 50%.

The compressibility of TDA should be considered in any engineering designs as it impacts the amounts of material required for a project. For example, Figure 3, **Tire Chip Compressibility**, shows that an average 12 inch thick leachate collection layer (comprised of TDA) could compress approximately 30% under 75 feet of waste – leaving an effective thickness of ~8.7 inches.

Table 3: **Compressibility of Different Size Tire Shreds** was assembled by Reddy and Marella and shows research relationships between TDA size and compressibility determined from prior research studies. (1)

Table 3: Compressibility of Different Size Tire Shreds*

Reference	Tire Shred Size (inch)	Compressibility (%)	Specific Test Conditions (Stress in psf)
Hall, 1991	0.75-1.5	30	1440
Humphrey et al., 1992, ASTM 1998	0.08-2	33-37	4176 (compacted)
	0.08-2	52	4176 (loose)
	0.08-1	33-35	4176 (compacted)
	0.08-1	45	4176 (loose)
Manion and Humphrey, 1992, ASTM, 1998	0.08-3	38-41	4176 (compacted)
	0.08-2	29-37	4176 (compacted)
Ahmed and Lovell, 1993	0.5-1.5	27	-
Newcomb and Drescher, 1994	1.18	25	104
		40	8532
Edil and Bosscher, 1994	2-3	37	14400
Zimmerman, 1997	8-16	55	793
Nickels and Humphrey, 1997, ASTM, 1998	3	18-28	522
Reddy and Saichek, 1998	0.5-5.5	31	665
	0.5-5.5	50	3400
	0.5-5.5	65	21000

*Table obtained from Reference #1

Figure 3: **Tire Chip Compressibility,** was taken from a Tire Chip Utilization Study conducted by HDR Engineering, Inc. for the Nebraska State Recycling Association and shows a range of compressibility data compiled from prior tire research. (22)

Figure 3: Tire Chip Compressibility*

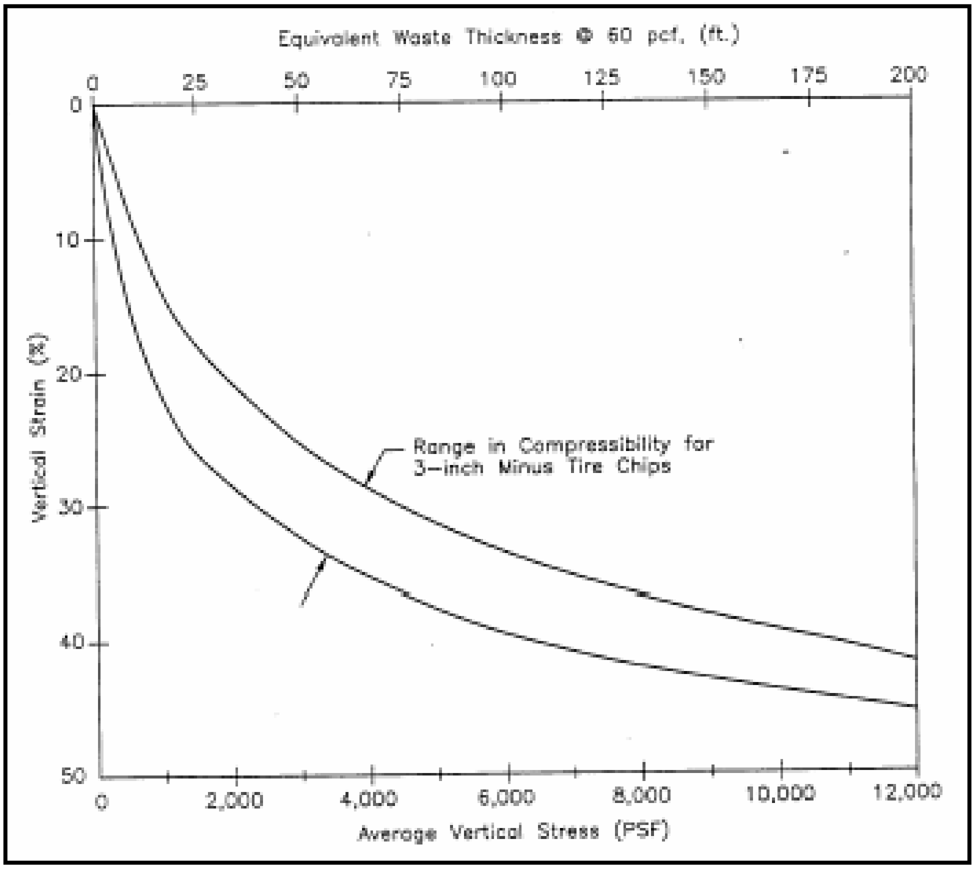


*Figure obtained from Reference #22

Table 4: **Compressibility of Tire Derived Aggregates,** shows the anticipated range of vertical strain for a given level of vertical stress.

Table 4 [1]
COMPRESSIBILITY OF TIRE DERIVED AGGREGATES

AVERAGE VERTICAL STRESS LB/IN.^{2} (KN/M^2)	ANTICIPATED RANGE OF VERTICAL STRAIN (%)
10 (21)	19-33
20 (42)	25-37
30 (63)	29-42
40 (84)	33-44
50 (105)	36-46
60 (126)	39-48
70 (147)	40-50

1. Reference #11
2. Shred maximum size 1 to 3 in. (25 to 75 mm)

Two Primary Mechanisms Causing Tire Compression

1. Bending and orientation of the TDA into a more compact spacing arrangement.
2. Compression of individual TDA under stress.

TDA Compression Characteristics

1. TDA that is initially placed loosely is compressed more than TDA that is initially slightly compacted.
2. Larger TDA pieces appear to compress more than smaller TDA pieces.

Definition: Shear Strength

The shear strength between two particles is the force that must be applied to cause a relative movement between the particles. Shear strength is a fundamental mechanical property that governs bearing capacity and slope stability.

A research review of prior studies, conducted by GeoSyntec Consultants, Inc. for the California Integrated Solid Waste Management Board, indicated that TDA and TDA/soil mixtures had a shear strength range of values that were at least comparable to typical values of municipal solid waste - tending to indicate that TDA use should not have a detrimental effect on landfill stability. (11)

Table 5: **Shear Strength of Different Size Tire Shreds,** was assembled by Reddy and Marella and shows research relationships between tire shred size and shear strength. (1)

Table 5: Shear Strength of Different Size Tire Shreds*

Reference	Tire Shed Size (inch)	C (psf)	Friction Angle	Specific Test Conditions/Normal Stress (psf)
Bresette, 1984	2-inch square	540	21	
	2-inch shredded	660	14	
Ahmed and Lovell, 1993	0.5	747	20.5	Standard compaction & 20% strain as failure
	1	818	24.6	Modified compaction energy & 20% strain as failure
		694	25.3	Standard compaction energy & 20% strain as failure
		779	22.6	50% standard compaction energy & 20% strain as failure
Humphrey et al., 1993	<1.5	180	25	Normal stress range: 400-1500 psf
	<2.0	90-160	21-26	
	<3.0	240	19	
Foose, 1993, Foose et al., 1996	<2, 2-4, and 4-6	0-62.6	30	146-1460 psf
Edil and Bosscher, 1994	2-3	-	37-43	0
		-	85	Compacted Condition
Black and Shakoor, 1994	<0.04	100	30	Tested at dry unit weight of 33 pcf
	0.04-0.16	70	31	
	0.16-0.27	130	27	
Duffy, 1995	2	150	27	
Cosgrove, 1995	1.5	69	38	Saturated
	3	90	32	
Bernal et al., 1996	2	0	17-35	17 Degrees at 5% strain, 35 Degrees at 20% strain
Masad et al., 1996	0.18	1462	6	10% strain
		1482	11	15% strain
		1712	15	20% strain
Cecich et al., 1996	0.2-0.6	147	27	ASTM D3080
Andrews and Guay, 1996	1-2	80	27.5	
Wu et al., 1997	<0.08	0	45	Tire shreds with out steel-triaxial tests under confining pressure of 720-1148 psf
	<0.37	0	47-60	
	<0.74	0	54	
	<1.5	0	57	
Gebhardt, 1997	1.5-55.1	65	38	115-585 psf Peak failure criterion
	1.5-55.1	0	38	115-585 psf 10% failure criterion

*Table obtained from Reference #1

Research on Shear Strength Tends to Indicate:

1. That there is no correlation between TDA size and shear strength. (1)
2. Larger TDA sizes [minimum of 25mm (1') to 50mm (2")] possess shear strengths that are comparable to conventional drainage materials, like sand. (1)

Definition: Water Absorption

The amount of water absorbed onto the surface of a particle and is expressed as the percentage (%) of water (by weight).

Water absorption capacity for TDA generally ranges from 2% to 4%. (2)

Definition: Combustibility

The potential of a material to react vigorously with oxygen to produce heat and light.

Both TDA and whole tires have a flash point of approximately 580^{o} F (3).

Under the right conditions, TDA has the potential to create an internal heating reaction that could lead to a fire.

Potential Causes of Internal Heating Reactions:

1. Oxidation of exposed steel belts
2. Oxidation of rubber
3. Microbial Action

Conditions That May Lead to Internal Heating Reactions in TDA Construction Projects:

1. Access to air;
2. Access to water;
3. Retention of heat caused by a high insulating value;
4. Large fill thickness **(TDA projects greater than 3m (10') thick are not recommended by ASTM);**
5. Large amounts of exposed steel belts;

6. Smaller TDA sizes and excessive amounts of granulated rubber particles, and;
7. Presence of inorganic and organic nutrients.

Research has shown that historical, self-ignited TDA fill fires were associated with projects where TDA was at least 6m (~20 feet) in compacted thickness.

Case Study on Combustibility

Garfield County, Washington Tire Fire, 1996

Brownfield Environmental Construction was utilized by the Washington Department of Ecology to remove and extinguish a road bed constructed of recycled tire chips (TDA). The TDA had been used in place of fill dirt in an attempt to save money and provide a market for the use of recycled tires.

Exothermic tire reaction research has concluded that using TDA in depths of more than 12 feet can create heat. Post project research on the Garfield County project concluded that heat formed from the friction of movement and the oxidization of the steel belting in the TDA caused it to ignite. The size of the project area filled with TDA was 70 feet deep by 200 feet wide by over 350 feet in length (ASTM now recommends using no deeper than 3m (10') of tire chips).

Brownfield designed and built a water chilling system to cool the chips as they were excavated. This process brought the temperature down to less than 100° Fahrenheit. This enabled Brownfield to excavate and transport more than 62,000 cubic yards of tire chips.

Excavation of Tire chips After Exothermic Heating Reaction

ASTM D6270 advises that tire derived aggregate projects not be greater than 3m (10') in thickness.

SECTION 4: Other Issues of Note:

Compatibility with Geosynthetics and Liners

Exposed wire from TDA presents a significant puncture hazard for any geosynthetic layer that may be used in a civil engineering project.

The ***New York Department of Environmental Conservation*** recommends that a minimum 9 to 12 inch layer of soil or aggregate be placed between the geomembrane and the TDA layer. (3) The Department does not recognize that geosynthetic materials provide adequate puncture protection from exposed wires in TDA. (3)

The ***state of Ohio*** suggests three options for the protection of the geomembrane layer when using TDA: (7)

1. If using debeaded TDA, place a geotextile (minimum average roll value of at least 8 oz/yd^2) between the shredded tires and the geomembrane.
2. If using TDA containing bead wire, place a layer of sand (10" layer unless otherwise determined by project engineer) or other appropriate material between the TDA and geomembrane layers.
3. If using TDA containing bead wire, place a puncture resistant geotextile or geocomposite (minimum average roll value mass per unit area of at least 16 oz/yd^2 and a puncture resistance of at least 283 lbs to 341 lbs) between the TDA and geomembrane layers.

Research by HDR Engineering, Inc. in a study conducted for the Nebraska State Recycling Association concluded that a granular cushion layer is necessary between TDA and geomembrane layers to provide puncture protection. HDR designs called for utilizing 12" of material (meeting a C-33 FA standard) over a geomembrane liner and 32 oz/yd^2 geotextile and 6" of material (meeting a C-33 FA standard) over a clay liner. (22)

Deployment of a geotextile over a TDA leachate collection layer.

Source: Ohio DNR

Exposed Wires

Exposed wires in TDA may cause an oxidation hazard when exposed to water or a puncture hazard when exposed to a landfill liner. Exposed wires also are of concern for worker and equipment safety.

Tire chipper maintenance is important for maintaining quality TDA with minimal wire exposure.

This TDA is from a tire chipper in good working order.

Long Strands of TDA and wire indicates that chipper blades are in need of replacement

Worker Safety

Worker safety should also be a concern in the deployment of TDA. Eye protection, hard hats, heavy gloves and steel shank/toe protected boots are all recommended. A safety vest is always a good idea when working in the vicinity of heavy equipment.

Uniformity and Quality

Regular cleaning, maintenance, and lubrication of tire processing machinery are vital steps for the production of a uniform product. Fines can affect the hydraulic conductivity, compressibility, and combustibility of TDA.

TDA derived from dump site clean-ups or from the bottom of stock piles should be screened and/or washed to remove fines and dirt.

Tire Derived Aggregate Quality Concerns

- **TDA should be kept as clean as possible before installation.**
- **TDA should not contain dirt clods, loose wires, or be coated with fines.**
- **TDA should be free from excess oil, grease, gasoline, diesel fuel, etc, that could create a fire hazard.**
- **TDA should be free from wood debris and fibrous organic matter.**
- **TDA should not contain material derived from tires that were previously subjected to fire as the heat may have liberated petroleum products that could create a fire hazard.**

Tires previously exposed to heat/fire <u>should not</u> be used in civil engineering applications.

Source: Iowa DNR

Proper Storage of Stockpiled Material

One major impediment to using TDA in landfill applications is the ability to find sufficient quantities of processed material to keep up with landfill construction activities.

Because a "just in time" delivery schedule is usually impractical for most large scale landfill projects, landfills will often need to stockpile and store TDA in an on-site staging area. It is critical that landfills plan ahead and reserve adequate space for storage and eventual deployment activities.

Recommended Criteria for Temporary Storage of Tire Chips*

*Obtained from Iowa Administrative Code – IAC 567-117

1. Ensure the storage area will be in compliance with site permits.
2. For piled processed tires that have been shredded or ground into pieces that are 9 inches or smaller:
    - Vertical dimension should not exceed 15 feet.
    - Length of pile should not exceed 100 feet.
    - Width of pile should not exceed 50 feet.
    - Volume of pile should not exceed 75,000 ft^3.

    For piled processed tires that have been shredded or ground into pieces that are larger than 9 inches:
    - Vertical dimension should not exceed 10 feet.
    - Length of pile should not exceed 100 feet.
    - Width of pile should not exceed 50 feet.
    - Volume of pile should not exceed 50,000 ft^3.
3. Located 50 feet from any property line, street, public right-of-way, or building.
4. Located away from potential ignition sources (work areas, main traffic areas, etc).
5. Located 50 feet from any combustible materials (including trees/brush).
6. 50 foot fire lane between storage piles.
7. A 20-pound Class ABC dry chemical fire extinguisher should be available within 100 feet of any one portion of the tire storage area.
8. Site graded to prevent standing pools of water and limit the runoff and run-on of precipitation.

Other TDA Storage Tips:

1. Use of temperature probes/thermal couples inserted into TDA storage piles may assist with monitoring internal temperatures during prolonged storage periods.
2. Efforts should be made to keep TDA stockpiles free of wind blown debris and other contaminates.
3. Landfills may find it useful to have a portable water wagon available to minimize dust during TDA staging operations and to cool down storage piles as necessary.
4. Operators should use caution when moving TDA to avoid mixing and contaminating it with underlying soils.

SECTION 5: Engineered Landfill Applications for Scrap Tires

Leachate Collection Layer

Definition: Leachate Collection Layer

An engineered landfill layer that provides positive control and discharge of landfill leachate. The layer is typically located directly above the landfill's bottom liner.

Federal Requirements

The Code of Federal Requirements (Title 40, Part 258) requires MSW landfills to install a leachate drainage layer:

"New MSWLF units and lateral expansions shall be constructed"…..(2) With a composite liner… and a leachate collection system that is designed and constructed to maintain less than a 30-cm depth of leachate over the liner."

Iowa Permitting Requirements

Any leachate collection system design incorporating TDA must be approved by engineering staff at the Iowa Department of Natural Resources.

Iowa Administrative Code – IAC 567-117.8(6)f states that the following application is considered an acceptable beneficial use for shredded waste tires:

"Landfill drainage medium at a permitted municipal landfill, provided that the medium meets engineering and design requirements for the landfill's operating permit, pursuant to 567 – Chapter 102."

State of Iowa Code - IAC 113.26(11)a(3)

A drainage layer must be placed immediately above the landfill liner. This drainage layer shall consist of a minimum of 1 foot of soil with a coefficient of permeability of 1 × 10^{-3} cm/sec (2.8 ft/day) or greater.

Tire Derived Aggregate (TDA) Needs

While utilization of whole tires has been approved in prior Iowa leachate collection layer projects, **the Iowa DNR has expressed a current preference for landfill leachate projects utilizing 3" to 4" nominal TDA** – unless engineering documentation is provided to substantiate a viable alternative design. (23)

Table 4: **Compressibility of Tire Derived Aggregates**, can be used to estimate the initial thickness of TDA needed to account for overburden pressures. (See page 18)

TDA ready for final staging and spreading - Clarke County Landfill.
Source: **BARKER LEMAR ENGINEERING CONSULTANTS**

Table 6: **Scrap Tire Yield**, estimates average tire derived aggregate yields.

TABLE 6 [4]
Scrap Tire Yield

TIRE DERIVED AGGREGATE SIZE IN. (MM)	DENSITY(1)	AVERAGE UNIT WEIGHT(2) LB/YD³ (KN/M³)	AVERAGE YIELD(3) TIRES/ YD³ (TIRES/M³)
2 TO 3 (50 TO 75)	LOOSE DENSE	740 (4.3) 1,270 (7.3)	37 (48) 64 (84)
1 TO 2 (25 TO 50)	LOOSE DENSE	810 (4.7) 1,300 (7.4)	40 (52) 65 (85)
< 1 (< 25)	LOOSE DENSE	> 810 (> 4.7) > 1,300 (> 7.4)	> 40 (> 52) > 65 (> 85)

1. Loose - indicates TDA loosely placed
2. Dense - indicates TDA compacted and compressed 15% to their final in-place volume by the weight of overlying soil
3. Data compiled from Humphrey et al. [1993] and Ahmed [1993]
4. Assumes an average weight of a typical passenger car tire of 20 lb (9 kg)
5. Reference #12

Tire Derived Aggregate (TDA) Layer Placement

The required thickness of the leachate drainage layer will need to be calculated taking into account the compression that will inevitably occur as waste and final cover are placed. Anticipated stress levels should be evaluated for each particular landfill, based on average compaction densities and final elevations.

Many leachate control designs recommend the incorporation of a geobarrier above the drainage layer to reduce infiltration of particulates into the TDA layer.

A report produced by HDR Engineering, Inc. for the Nebraska State Recycling Association states that less than one inch of TDA provides equivalent flow capacity as 12 inches of washed sand; however, it was recommended that a minimum six (6) inches of TDA should be used to accommodate conventional placement techniques, construction tolerances, and compressibility with a six (6) inch layer of fine aggregate placed between the TDA and geomembrane to act as a cushion layer. (10)

TDA containing bead wire is not recommended to be placed next to geosynthetic barrier liners.

> ***A report by GeoSyntec Consultants, Inc. for the California Integrated Waste Management Board*** suggests that if TDA containing bead wire is utilized, a minimum of 6" of sand or other approved barrier cushion should be placed between the TDA and the geosynthetic barrier liner. (4) (11)
>
> ***The New York Department of Environmental Conservation*** recommends that a 9 to 12 inch layer of soil or aggregate be placed between the geomembrane and the TDA layer. (3)

Tire Derived Aggregate (TDA) Size

Class I Fills: *For use in applications in layers less than 1m (~3') thick*. (4)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

Class II Fills: *For use in applications in layers ranging from 1m (~3') to 3m (~10') thick.* (4)

- Have a maximum of 25% (by weight) passing the 38 mm (1.5") sieve.
- Have a maximum of 1% (by weight) passing the 4.75 mm (~.19") sieve.
- Free from fragments of wood, wood chips, and other fibrous organic matter.
- Less than 1% (by weight) of metal fragments not at least partially encased in rubber.
- Metal fragments partially encased in rubber shall protrude no more than 25 mm (~1") from the cut edge of the TDA on 75% of the pieces and nor more than 50 mm (~2") on 100% of the pieces.
- Projects should be constructed in a way that reduces infiltration of water and air.
- No direct contact between TDA and soil containing organic material (i.e. topsoil).
- Drainage features located at the bottom of the fill that could provide free access to air should be avoided.

A Paper developed by the New York Department of Environmental Conservation**, recommends that if the TDA landfill leachate layer is being utilized for hydraulic performance <u>and</u> thermal protection, **Dr. Dana Humphrey's (University of Maine)** "Type A Drainage and Insulating Media" be utilized – as shown in Table 7: **Type A Drainage and Insulating Media. (3)

TABLE 7*

TYPE A DRAINAGE AND INSULATING MEDIA

SIEVE SIZE INCHES (MM)	MINIMUM % PASSING BY WEIGHT
4 (100)	100
3 (75)	90
#4 (4.75)	5

*** Reference #3**

The Iowa Department of Natural Resources advocates the use of a <u>3" to 4" nominal sized TDA</u> for leachate collection layers. In come cases larger material, up to 12" in size may be acceptable if substantiated by engineering and scientific data.

<u>Logistics and Compaction</u>

Material Logistics

Spreading and placement of TDA is normally conducted with a track mounted dozer, loader, or steel wheeled compactor with a blade. For slopes of 3:1 or flatter, smaller equipment has been shown to be more efficient for spreading 3 inch shreds. (11)

Compaction

Compaction techniques are utilized to rearrange and densify TDA to help create a stable base for subsequent layers.

TDA may be compacted with a sheepsfoot, landfill compactor, tracked bulldozer, smooth drum roller or equivalent equipment. Generally 4 to 6 passes are required. (11)

Sheepsfoot rollers and compactors tend to "fluff" the surface of a layer of TDA and should generally not be used for compacting the last lift of TDA. (11)

To achieve a typical leachate drainage layer thickness of 12 to 18 inches, TDA is typically placed in 1 to 2 lifts and compacted. (11)

Side Slopes – ***Ohio EPA*** recommends that TDA be deployed against the interior side slope and be pushed uphill in amounts and in a manner that reduces stress on the liner material interface. Once deployed no equipment should travel on the slope. (7)

Caution: Consistent placement of TDA in lifts less than 9 to 12 inches in depth is difficult due to the tendency for exposed metal wires to clump together. (11)

Restriction Considerations

1. ***Wire***
   Loose, exposed, and protruding wire beads have the ability to puncture a geosynthetic barrier layer. Belt wires can scratch geomembranes. An appropriate "cushion" layer should be utilized between membrane layers and TDA.

2. ***Contaminants***
   Care should be taken to ensure that TDA is kept as clean as possible prior to installation.

3. ***Leachate Collection System Pipe Bedding***
   Ohio EPA <u>does not</u> recommend placement of TDA as leachate collection pipe bedding due to the compressible nature of TDA and the risk of the pipe crushing or deflecting under the weight of the overlying waste. (7)

   A report prepared by Robert Phaneuf, P.E. for the New York State Department of Environmental Conservation suggests that thought be given to the use of <u>conventional soil drainage media bedding</u> around leachate collection pipes. (3)

TDA should be kept clean and free from excess dirt and debris.

The TDA on the left is typical, clean material.

The TDA on the right has been contaminated with dirt and should be washed and screened before use.

Source: Ohio DNR

LEACHATE COLLECTION CASE STUDY

Black Hawk County Sanitary Landfill – Cell X Leachate System
Waterloo, IA

Construction started 1999

Purpose:
A new operating area of approximately 20 acres was to be constructed to replace an area opened in 1991 which was rapidly approaching capacity. The original area had been constructed to proposed Subtitle D rules with a dewatering system, four foot clay liner and a leachate system with sand collection media. Similar construction was proposed for the new area, but for a number of technical and financial reasons, permission was sought to substitute shredded tires for the sand in the collection system.

Detail:

- Phase 1 construction consisted of developing half the cell, approximately 9.5 acres.
- The engineering analysis indicated that a 21 inch thick layer of 3 inch nominal shreds could be used to replace conventional aggregates.
- For Phase 1, approximately 32,000 yd^3 of TDA were utilized.
- TDA was stockpiled and placement began immediately upon completion and certification of the liner. TDA was then placed as received until the entire lined area was covered.
- The first waste was placed in Cell X early January 2000.
- Phase 2 consisted of development of the remaining portion of Cell X and was started the fall of 2000.
- Approximately 20,000 $yd^3$of TDA was incorporated in Phase 2.
- Phase 3 construction began in the fall of 2004 and consisted of construction of liner joining Cell A and Area E to provide additional lined capacity.
- Eighteen inches of TDA (900 yd^3) was used in Phase 23

Outcomes:

- *"We've been happy with the performance of the TDA projects at our facility and will look at using TDA in future development projects."*

  - Gary Wilcox, Solid Waste Administrator, Black Hawk County Solid Waste Management Commission

LEACHATE COLLECTION CASE STUDY
Metro Park East Landfill - Leachate Recirculation Trench
Mitchellville, IA

Installed in 2003.

Purpose:

Used for as-needed recirculation of leachate back into the facility's fill area when head levels in the leachate storage lagoon elevate during the winter months. Leachate is normally treated through an on-site Constructed Wetlands Treatment System (CWTS).

Detail: (See Appendix D, Case Study Supplement 1)

- ~600' of solid HDPE SDR 17 pipe installed for transfer of leachate from the lagoon to the recirculation trench.
- 106' of 4" perforated HDPE SDR 17 pipe installed in the leachate recirculation trench.
- 4" perforated pipe was bedded in 2 feet of 3" to 4" nominal size TDA and backfilled with uncompacted clay.
- As needed, leachate is pumped from the CWTS holding lagoon and injected into the leachate recirculation trench.
- A valve was installed at a manhole location to allow fluid to drain from the pipe following pumping activities.

Operational Procedures:

- Piping inspected at start up and inspected weekly to verify integrity of the system.
- Slopes in the vicinity of the recirculation area were visually inspected for seepage on a daily basis.
- Seepage would be noted and recirculation reduced until seepage was no longer noted.
- Leachate head measurements in the area were conducted monthly.

Outcomes:

- Trenches should ideally be constructed deep and narrow into the waste area versus wide and shallow.
- The system would be ideally constructed as fill progress versus installation after final fill elevations have been obtained.
- Staging the TDA as close to the project site as possible is preferable to minimize delays and potential dirt/debris contamination.

- *"The TDA we utilized was relatively easy to work with. Installation was similar to that of traditional aggregate."*

  - Rich Krumel, Sr. Field Technician, Barker Lemar Engineering Consultants

TDA used as backfill over perforated leachate collection lines at Metro Park East Landfill.

Source: **BARKER LEMAR ENGINEERING CONSULTANTS**

LEACHATE COLLECTION CASE STUDY
Audubon County Sanitary Landfill – Leachate Recirculation Trench
Audubon, IA

Installed in 2002

Purpose:
TDA was utilized to backfill trenches excavated within the existing waste boundary of the facility for the purpose of leachate collection and extraction.

Detail: (See Appendix D, Case Study Supplement 2)

- ~340' of 4" HDPE SDR 17 perforated pipe was placed in trenches in the targeted fill area and backfilled with 3' to 5' of 3" to 4" nominal size TDA.
- The perforated pipe was connected to approximately 890' of 2" HDPE SDR 17 solid pipe that transports the pumped leachate from an existing leachate lagoon on the site property.
- The trenches within the waste boundary were capped with the excavated waste and soils and covered as per normal operating procedures.
- Following backfilling, a ½ horsepower pump, with pumping capabilities of 25 gallons per minute, was installed with valve and check valves for maintenance and back flow prevention purposes.
- A pump control was also installed to avoid pump damage in the event that the lagoon is pumped dry.

Outcomes:

- TDA was relatively easy to stage and install. No major problems encountered with handling and logistics.

TDA used as backfill at Audubon County Sanitary Landfill leachate recirculation project.
Source: **BARKER LEMAR ENGINEERING CONSULTANTS**

Audubon County Sanitary Landfill leachate recirculation piping prior to backfilling trench with TDA.

Source: **BARKER LEMAR ENGINEERING CONSULTANTS**

Audubon County Sanitary Landfill leachate recirculation piping being backfilled with TDA

Source: **BARKER LEMAR ENGINEERING CONSULTANTS**

LEACHATE COLLECTION CASE STUDY
Des Moines County Regional Sanitary Landfill – Leachate Toe Drain
Burlington, IA

Installed in 2001

Purpose:
A toe drain utilizing TDA as drainage media was constructed to collect leachate from the toe of an existing landfill cell.

Detail: (See Appendix D, Case Study Supplement 3)

- A trench was excavated at the bottom of the target waste boundary and a 4" HDPE SDR 17 perforated pipe was placed at the trench base.
- The perforated pipe was fused to an existing 6" HDPE header pipe to connect to the facility's leachate collection system.
- A 4" gate valve was installed in event the flow must be stopped for maintenance purposes.
- The trench was backfilled with 4" to 6" nominal sized TDA.
- 24" of uncompacted soil was placed above the TDA for vegetative growth.
- A 6 oz nonwoven geotextile liner was installed between the uncompacted soil and the TDA.
- 1,004 tons of tire TDA were used.

Outcomes:

- Recommend staging materials as close to final project area as possible to minimize on-site logistics.
- *"We did not experience any unusual problems with using TDA in place of traditional aggregate materials. I recommend that project mangers work with their TDA suppliers to ensure that adequate supplies of TDA will be available for the project. Facilities should consider stockpiling TDA on-site to maintain the quantities needed for construction."*

  - CJ Lage, Project Manager, Barker Lemar Engineering Consultants

Excavated Toe Drain Trench at Des Moines County Regional Sanitary Landfill.

Source: **BARKER LEMAR ENGINEERING CONSULTANTS**

Des Moines County Regional Sanitary Landfill Toe Drain Trench is covered with Filter Fabric Prior to Backfilling.

Source: **BARKER LEMAR ENGINEERING CONSULTANTS**

LEACHATE COLLECTION CASE STUDY*
Michigan State University Study – Leachate Recirculation Blanket

*Information obtained from Reference #20

Purpose:
The Michigan State University study utilized a "permeable blanket" consisting of TDA to evaluate the efficiency of the system for subsurface recirculation of leachate back into a landfill.

Michigan State Study Design Considerations:

- A non woven geotextile was laid horizontally on the existing MSW surface (test area was 180' x 30').
- Approximately .6m (24") of .1m (4") wide by .4m (16") to .6m (24") long TDA was placed on the geotextile.
- A perforated HDPE pipe was installed at the center of the test section, parallel to the short side, for injecting leachate.
- A non-woven geotextile was placed over the TDA layer.
- The upper geotextile was covered by MSW.

Michigan State Study Conclusion:
Research indicated efficient hydraulic recirculation across the entire blanket area.

Potential Benefits of Using a Recirculation Blanket:

- Reduction in leachate treatment and disposal costs.
- More uniform distribution of leachate.
- More uniform settlement across waste areas.

Landfill Gas Collection Layer

Definition: <u>Gas Collection Layer</u>

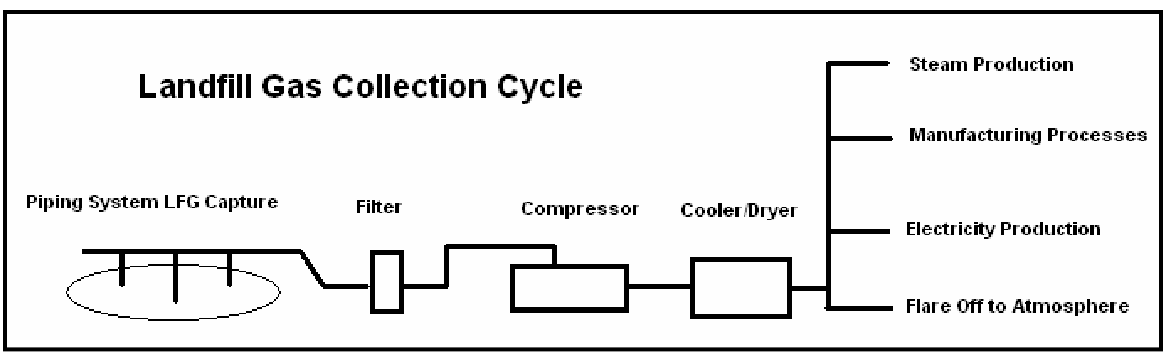
An engineered landfill layer that provides gas collection and venting to control discharge of landfill gas under active or passive extraction. This layer is typically located directly beneath the infiltration layer in the closure cap.

Gas Collection Layers:

- Typically consist of an engineered system of horizontal layers, horizontal trenches, and vertical boreholes filled with granular material.
- May include a perforated pipe to enhance gas removal.
- Horizontal collection layers typically are 6 to 12 inches thick.

Figure 3: **Landfill Gas Collection Cycle**, shows how collected gas may be used for steam or electric production, manufacturing processes, or simply flared off to the atmosphere.

Figure 3: Landfill Gas Collection Cycle



Federal Requirements

The requirements for management of fugitive gases from landfills are found in 40 CFR Part 60 Subpart WWW. Threshold values above which regulation applies under this part are found in 40 CFR Part 60 § 60.752. These threshold values are 2.5 million cubic meters or 2.5 million megagrams. Either threshold value may be used for comparison to determine application of the regulation to the site.

Iowa Permitting Requirements

Any landfill gas collection system design incorporating TDA must be approved by engineering staff at the Iowa Department of Natural Resources.

Tire Derived Aggregate (TDA) Needs

Approximately one 45,000 ft^3 (1,250 m^3) TDA stockpile is required to produce a 12-in (300-mm) thick landfill gas collection layer over a one acre area. (12)

A typical landfill gas collection layer is 6 to 12 inches thick. (12)

1 cubic yard of TDA = 60 to 70 whole passenger tires (12)

Table 4: **Compressibility of Tire Derived Aggregates** *(See Page 18)*, can be used to estimate the initial thickness of TDA needed to account for overburden pressures.

Table 6: **Scrap Tire Yield** *(See Page 33)*, estimates average TDA yields.

Tire Derived Aggregate (TDA) Layer Placement

The compressibility of TDA must be considered when constructing an overlying clay composite liner over a landfill gas collection system utilizing TDA.

Construction of a compacted clay liner (CCL) **directly** over 12 inches of foundation soil underlain by 12 inches of TDA is NOT feasible due to the relatively high compressibility of the TDA and development of numerous cracks in the CCL. (12)

It appears that an 18-inch thick soil layer over 6 inches of TDA provides an adequate surface for construction of the CCL with a hydraulic conductivity of 1 x 10^{-6} cm/s or less. (12)

To reduce soil infiltration into the TDA layer, an adequate geotextile may be used as a separator between the TDA and overlying soil layer.

TDA containing bead wire is not recommended to be placed next to geosynthetic barrier liners.

> ***A report by GeoSyntec Consultants, Inc. for the California Integrated Waste Management Board*** suggests that if TDA containing bead wire is utilized, a minimum of 6" of sand or other approved barrier cushion should be placed between the TDA and the geosynthetic barrier liner. (11)
>
> ***The New York Department of Environmental Conservation*** recommends that a 9 to 12 inch layer of soil or aggregate be placed between the geomembrane and the TDA layer. (3)

To place geomembrane directly over TDA, a field trial is recommended to demonstrate that the geomembrane can be placed, seamed, and covered with soil without damaging the geomembrane (#12).

Tire Derived Aggregate (TDA) Size

Class I Fills: ***For use in applications in layers less than 1m (~3') thick*.** (4)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

Class II Fills: ***For use in applications in layers ranging from 1m (~3') to 3m (~10') thick.*** (4)

- Have a maximum of 25% (by weight) passing the 38 mm (1.5") sieve.
- Have a maximum of 1% (by weight) passing the 4.75 mm (~.19") sieve.
- Free from fragments of wood, wood chips, and other fibrous organic matter.
- Less than 1% (by weight) of metal fragments not at least partially encased in rubber.
- Metal fragments partially encased in rubber shall protrude no more than 25 mm (~1") from the cut edge of the TDA on 75% of the pieces and nor more than 50 mm (~2") on 100% of the pieces.
- Projects should be constructed in a way that reduces infiltration of water and air.
- No direct contact between TDA and soil containing organic material (i.e. topsoil).

- Drainage features located at the bottom of the fill that could provide free access to air should be avoided.

A report by GeoSyntec Consultants, Inc. for the California Integrated Waste Management Board suggests that TDA used for gas collection should have a maximum dimension, measured in any direction, of 12-in. and conform to the schedule in Table 8: **Tire Derived Aggregate Size (Landfill Gas Layer)**. (12)

TABLE 8 [3]
Tire Derived Aggregate Size (Landfill Gas Layer)

SIEVE SIZE[(2)] IN. (MM)	MINIMUM PASSING (% BY WEIGHT)
12 (300)	**100**
6 (150)	**95**
3 (75)	**50**
#4 (4.75)	**5**

1. Specifications of tire derived aggregates mixed with sand and/or gravel, prior to use as LFG collection material, should allow for a greater percentage of particles passing #4 sieve depending on the mixture.
2. Indicates square mesh sieve
3. Reference #12

Logistics and Compaction

Material Logistics

Spreading and placement of TDA is normally conducted with a track mounted dozer, loader or steel wheeled compactor with a blade. For slopes of 3:1 or flatter, smaller equipment has been shown to be more efficient for spreading 3 inch shreds. (12)

Compaction

Compaction rearranges and increases the density of the TDA to assist in creating a stable working surface.

TDA may be compacted with a sheepsfoot, landfill compactor, tracked bulldozer, smooth drum roller, or equivalent equipment. Generally 4 to 6 passes are required. (12)

Sheepsfoot rollers and compactors tend to "fluff" the surface of a layer of tire derived aggregates and should not be used for compacting the last lift of TDA. (12)

A typical gas collection layer thickness of 12 to 18 inches, may be achieved through 1 to 2 compacted lifts of TDA. (12)

Caution: Consistent placement of TDA in lifts less than 9 to 12 inches in depth is difficult due to the tendency for exposed metal wires to clump together. (12)

Exposed steel in TDA can puncture the rubber tires on construction vehicles. Avoid driving over shreds with tube tire vehicles. Consider using vehicles with steel wheels, solid tires, or tracks for deployment.

Restriction Considerations

1. ***Wire***

   Loose, exposed, and protruding wire beads have the ability to puncture a geosynthetic barrier layer. Belt wires can scratch geomembranes. An appropriate "cushion" layer should be utilized between membrane layers and TDA.

   If TDA without metal wires is used for landfill gas collection material, there is no need for placing a geotextile, geocomposite, or soil above the geosynthetic barrier layer. (12)

2. ***Contaminants***

   Care should be taken to ensure that TDA is kept as clean as possible prior to installation.

Landfill Gas Control Trench

Definition: Landfill Gas Control Trench

Typically located outside the landfill footprint and used to reduce lateral migration and to control discharge of landfill gas under active or passive extraction.

Federal Requirements

The Code of Federal Requirements (Title 40, Part 258) requires MSW landfills to ensure that the concentration of methane gas does not exceed the lower explosive limit for methane at the facility property boundary.

In cases were landfill gas may be migrating underground from a fill area and mitigation is necessary, a gas collection trench utilizing TDA may be a beneficial solution.

Iowa Permitting Requirements

Any landfill gas control trench system design incorporating TDA must be approved by engineering staff at the Iowa Department of Natural Resources.

Tire Derived Aggregate (TDA) Needs

Landfill gas control trenches may vary in both depth and width, depending on the actual engineering need for the specific project. Table 4: **Compressibility of Tire Derived Aggregates**, (see page 18) can be used to estimate the initial thickness of TDA needed to account for overburden pressures. Table 6: **Scrap Tire Yield**, (see page 33) estimates average tire derived aggregate yields.

Tire Derived Aggregate (TDA) Layer Placement

To reduce soil infiltration into the tire layer, a properly selected geotextile should be used as a separator between the TDA and overlying soil layer.

Tire Derived Aggregate (TDA) Size

Class I Fills: ***For use in applications in layers less than 1m (~3') thick***. (4)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

Class II Fills: ***For use in applications in layers ranging from 1m (~3') to 3m (~10') thick.*** (4)

- Have a maximum of 25% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 1% (by weight) passing the 4.75 mm (~.19") sieve.
- Free from fragments of wood, wood chips, and other fibrous organic matter.
- Less than 1% (by weight) of metal fragments not at least partially encased in rubber.
- Metal fragments partially encased in rubber shall protrude no more than 25 mm (~1") from the cut edge of the TDA on 75% of the pieces and nor more than 50 mm (~2") on 100% of the pieces.
- Projects should be constructed in a way that reduces infiltration of water and air.
- No direct contact between TDA and soil containing organic material (i.e. topsoil).

Table 8: **Tire Derived Aggregate Size (Landfill Gas Layer)** – (See page 48) provides additional information on TDA sizing specifications for landfill gas control structures. (12)

Logistics and Compaction

Placement of TDA in a trench is similar in technique to placement of traditional aggregate material like sand or gravel. Compaction is not necessary, however, trench design should allow for tire compressibility. (12)

Restriction Considerations

1. ***Contaminants***

   Care should be taken to ensure that TDA is kept as clean as possible prior to installation.

2. Water Table Concerns

ASTM D6270 does not recommend the use of TDA below the water table. If the landfill gas trench application will be excavated below the water table, it is recommended that the Project Engineer consider possible leaching outcomes.

Landfill Operations Layer

Definition: Operations Layer

Separates waste from and provides protection to the underlying landfill containment system. Typically located between a landfill's initial lift of solid waste and the leachate collection layer.

Federal Requirements for Operations Layer

The Code of Federal Regulations (Title 40, Part 258) does not require an operations layer at MSW landfills.

Iowa Permitting Requirements

Any landfill operations layer system design incorporating TDA must be approved by engineering staff at the Iowa Department of Natural Resources.

Tire Derived Aggregate (TDA) Needs

As a rough guide, 90,000 cubic feet of TDA is required to produce a 24-in thick operations layer over one acre of cell (the 24-in thickness allows for TDA compressibility since a typical operations layer thickness is 12 to 18 inches. (14)

Actual thickness of the operations layer should be calculated based on planned overlying waste and final cover.

Table 6: **Compressibility of Tire Derived Aggregates,** provides for guidance on the affects of vertical stress on TDA. (See page 18)

Tire Derived Aggregate (TDA) Layer Placement

To reduce soil infiltration into the TDA layer, an adequate geotextile may be used as a separator between the TDA and overlying soil layer.

TDA containing bead wire is not recommended to be placed next to geosynthetic barrier liners.

If TDA with bead wire is used as an operations layer over a geocomposite leachate drainage layer, then: (14)

- A minimum 12-in. thick soil layer should be placed between the TDA and the geosynthetic barrier material.

- Bead wires should protrude no more than 1 inch from the cut edge of the TDA on 75% of the pieces.
- Bead wires should protrude no more than 2 inches on 100% of the TDA.
- TDA should have less than 1% (by weight) of bead wire fragments that are not at least partially encased in rubber.

Tire Derived Aggregate (TDA) Size

Class I Fills: ***For use in applications in layers less than 1m (~3') thick**.* (4)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

Class II Fills: ***For use in applications in layers ranging from 1m (~3') to 3m (~10') thick.*** (4)

- Have a maximum of 25% (by weight) passing the 38 mm (1.5") sieve.
- Have a maximum of 1% (by weight) passing the 4.75 mm (~.19") sieve.
- Free from fragments of wood, wood chips, and other fibrous organic matter.
- Less than 1% (by weight) of metal fragments not at least partially encased in rubber.
- Metal fragments partially encased in rubber shall protrude no more than 25 mm (~1") from the cut edge of the TDA on 75% of the pieces and nor more than 50 mm (~2") on 100% of the pieces.
- Projects should be constructed in a way that reduces infiltration of water and air.
- No direct contact between TDA and soil containing organic material (i.e. topsoil).
- Drainage features located at the bottom of the fill that could provide free access to air should be avoided.

TDA used for a landfill operations layer should have a maximum dimension, measured in any direction, of 18 in. and conform to the schedule in Table 9: **Tire Derived Aggregate Size (Operations Layer)**. (14)

TABLE 9 [3]
Tire Derived Aggregate Size (Operations Layer) [(1)]

SIEVE SIZE[(2)] IN. (MM)	MINIMUM PASSING (% BY WEIGHT)
18 (450)	100
12 (300)	95
6 (150)	75

1. Tire derived aggregates to be mixed with soil, prior to use as operations layer material, shall also conform to these requirements.
2. Indicates square mesh sieve
3. Reference #14

Logistics and Compaction

Material Logistics

Spreading and placement is normally conducted with a track mounted dozer, loader, or steel wheeled compactor with a blade. For slopes of 3:1 or flatter, smaller equipment has been shown to be more efficient for spreading 3 inch TDA. (14)

Compaction

Compaction rearranges and increases the density of TDA to assist in creating a stable working surface.

A typical operations layer thickness of 12 to 24 inches may generally be achieved though 1 to 2 lifts of compacted TDA. (14)

TDA may be compacted with a sheepsfoot, landfill compactor, tracked bulldozer, smooth drum roller, or equivalent equipment. Generally 4 to 6 passes are required. (14)

Sheepsfoot rollers and compactors tend to "fluff" the surface of a layer of tire derived aggregates – this is sometimes acceptable for an operations layer. (14)

Caution: Consistent placement of TDA in lifts less than 9 to 12 inches in depth is difficult due to the tendency for exposed metal wires to clump together. (14)

Restrictions Considerations

1. **Metal Wires**
   Loose, exposed, and protruding wire beads have the ability to puncture a geosynthetic barrier layer. Belt wires can scratch geomembranes. An appropriate "cushion" layer should be utilized between membrane layers and TDA.

2. **Contaminants**
   Care should be taken to ensure that TDA is kept as clean as possible prior to installation.

Road Base

TDA has been used with mixed results as subbase material in roads and other paving applications.

In some areas of the country, TDA has been successfully utilized in wet or boggy areas and in areas with high soil compressibility to help “float” the road surface.

Engineering Characteristics That Make TDA Good for Road Base Applications

- Insulating value (8 times greater than gravel)
- High permeability
- Light weight

Iowa Permitting Requirements

Any landfill road base system design incorporating TDA must be approved by engineering staff at the Iowa Department of Natural Resources.

Iowa Administrative Code – IAC 567-117.8(6)c considers lightweight fill as an acceptable beneficial use for shredded waste tires if all of the following conditions are met:

1. The TDA is of uniform composition and sizing;
2. The TDA is not mixed with other solid wastes, vegetation, composted materials, or other processed tire products, including separated tire bead wire, steel cording or nylon fibers;
3. The TDA is not placed in direct contact with surface water or groundwater;
4. The TDA is isolated from overburden materials by a protective membrane or liner to prevent intrusion and settling of overburden; and
5. An Iowa-licensed professional engineer designs and supervises the incorporation of TDA in beneficial uses of this manner.

Tire Derived Aggregate (TDA) Needs

Should be determined based on specific engineering applications.

ASTM D6270 advises that tire derived aggregate projects not be greater than 3m (10’) in thickness.

Tire Derived Aggregate (TDA) Layer Placement

ASTM Standard D6270-98 mentions that TDA used under areas that are paved should be covered with a sufficient thickness of soil to limit deflections of overlying pavement from traffic loading.

Light Duty Use Paved Roads: May need as little as .8m (~2.5") of soil cover (4)

Heavy Duty Use Paved Roads: May need 1m (3') to 2m (6') of soil cover (4)

A November 1998 workshop sponsored by the Maine Local Roads Center and the New England Transportation Consortium presented information suggesting that TDA used as road fill should be placed in 12" thick lifts, compacted, and finally covered with a minimum of 24" of gravel. (15)

ASTM D6270-98 recommends in tire fill applications with a pavement over layer, that the TDA layer be completely wrapped in non-woven or woven geotextile to reduce the infiltration of soil particles. (4)

Tire Derived Aggregate (TDA) Size

Class I Fills: ***For use in applications in layers less than 1m (~3') thick***. (4)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

Class II Fills: ***For use in applications in layers ranging from 1m (~3') to 3m (~10') thick.*** (4)

- Have a maximum of 25% (by weight) passing the 38 mm (1.5") sieve.
- Have a maximum of 1% (by weight) passing the 4.75 mm (~.19") sieve.
- Free from fragments of wood, wood chips, and other fibrous organic matter.
- Less than 1% (by weight) of metal fragments not at least partially encased in rubber.
- Metal fragments partially encased in rubber shall protrude no more than 25 mm (~1") from the cut edge of the TDA on 75% of the pieces and nor more than 50 mm (~2") on 100% of the pieces.
- Projects should be constructed in a way that reduces infiltration of water and air.

- No direct contact between TDA and soil containing organic material (i.e. topsoil).

Road base soil cover depths should consider:

1. Thickness of the TDA layer;
2. Pavement thickness;
3. Loading conditions, and;
4. Other conditions as determined by project location/application.

MN/DOT Standard of Engineering Practice for the Use of Shredded Tires in Roadways*

Provides standard guidance for Minnesota engineered road applications using TDA as a sub layer:

- Soil pH must be verified between 5 and 9
- Must be encapsulated in geotextile
- Must not be mixed with sand, soil or other borrow material
- 5' to 6' of cover has worked well for paved roads – unpaved, low volume roads have been built with less cover.

*Reference #21

Logistics and Compaction

Material Logistics

Spreading and placement of TDA is normally conducted with a track mounted dozer, loader, or steel wheeled compactor with a blade. (12)

Compaction

Compaction rearranges and increases the density of TDA to assist in creating a stable working surface.

TDA may be compacted with a sheepsfoot, landfill compactor, tracked bulldozer, smooth drum roller, or equivalent equipment. Generally 4 to 6 passes are required. (12)

Sheepsfoot rollers and compactors tend to “fluff” the surface of a layer of tire derived aggregates and should not be used for compacted the last lift of TDA. (12)

Caution: Consistent placement of TDA in lifts less than 9 to 12 inches in depth is difficult due to the tendency for exposed metal wires to clump together. (12)

Restriction Considerations

1. **Contaminants**
   Care should be taken to ensure that TDA is kept as clean as possible prior to installation.

Study Highlight: Tire Derived Aggregate Road Base*

The **Maine Local Roads Center and the New England Transportation Center** have successfully utilized TDA in road fill applications and offer the following guidelines:

- 12” thick lifts, compacted, and covered with a minimum of 24” of gravel.
- Specifications meeting ASTM D 6270.
- Benefits: Provides good vehicle weight support, proper subbase drainage, and insulation to inhibit frost from reaching poor subgrade soils.

*Reference #15

Study Highlight: Tire Derived Aggregate Road Base*

Mille Lacs County Minnesota used TDA in two road areas where poor soil bases allowed roads to sink and fail.

An 80’ trench was excavated, 10 feet of TDA was installed in 12 inch lifts, tire material was covered with geofabric, and 3’ of soil was installed as top grade.

Eight years later (2005), the County Engineer’s office reports that the roads have “held up good.” (34)

*Reference #17

Study Highlight: Tire Derived Aggregate Road Base*

A study conducted by Metro Waste Authority for the Iowa Department of Natural Resources in 1999 concluded that landfills lacking sufficient clay resources for a standard road under base may find TDA as a viable subgrade for construction access roads and wet weather pads.

The project utilized 2” to 4” nominal sized TDA placed in one 8” lift and compacted with a light ground pressure dozer.

*Reference #16

SECTION 6: State and Local Approval Processes

State of Iowa Code - IAC 567-117.8(1)

"….The Department shall have the authority to determine if a proposed use of waste tires is beneficial and shall have the authority to approve or deny applications if such a benefit is not evident."

Whole Tires

*Approved End Uses of Whole Tires**

***From Iowa Administrative Code – IAC 567-117**

- Tire swings, sandboxes, or other equipment for child play areas on residential lots or at schools, care centers, and recreational areas;
- Dock bumpers at vehicle loading/unloading docks or marine docks;
- Crash barriers at racetracks;
- Agricultural uses to hold down covers over hay, silage, and other agricultural commodities. When not in use, the tires should be neatly stacked;
- Structures for military and police training at facilities under ownership or management of local, state, or federal agencies;
- Artificial fishing reefs and fish habitat structures constructed at facilities under ownership or management of a county conservation board, the department, or a federal agency;
- Stream bank erosion control and culvert outlet tire mats
- Construction of residential dwelling structures or other buildings for which a building permit has been obtained from local government officials;
- Culvert piping made from waste tires with a rim diameter of 21 inches or greater.

*Required Notifications and Approval for Whole Tire Uses**

***From Iowa Administrative Code – IAC 567-117**

Prior IDNR notification and approval is required for any use of whole tires in landfill applications.

All Beneficial Reuses of Whole Tires Must:

1. Incorporate design and construction measures that prevent the retention and stagnation of water.
2. Minimize risks to pubic health and safety caused by the breeding of disease-carrying insects and rodents.

Shredded Tires

*Approved End Uses of Shredded Tires**

***From Iowa Administrative Code – IAC 567-117**

1. Horizontal drainage structures (French drains) and constructed as follows:
    - The elevation of the drain outlet must be lower than the average seasonal groundwater table to allow gravity drainage through the drainage structure;
    - The drainage structure width shall be no less than 3 feet and no more than 6 feet;
    - The minimum depth of shredded tire material in the trench shall be greater than 4 feet;
    - The minimum thickness of backfill over the trench shall be 2 feet;
    - Headloss of water flowing through the drain shall be due to elevation changes only; and
    - Any site of end use to contain drainage structures composed of more than 300 cubic yards of shredded tires shall be constructed under the auspices of an Iowa-licensed professional engineer.

2. On-site wastewater treatment and disposal system construction, to include use of shredded tires in lateral trenches and as fill to cover distribution pipes under the following conditions:
    - Constructed and permitted according to 567 - Chapter 69;
    - TDA minimum dimension of 1 inch on any one side and a maximum dimension of 3 inches on any one side; and
    - Administrative authority responsible for issuance of permit has sole discretion to deny use of TDA based on any engineering or design principle concerns.

3. Lightweight fill in public roads, public road embankment construction, and other public civil engineering applications if all of the following conditions are met:
    - The tire derived aggregates are of uniform composition and sizing;
    - The tire derived aggregates are not mixed with other solid wastes, vegetation, composted materials, or other processed tire products, including separated tire bead wire, steel cording, or nylon fibers;
    - The tires are not placed in direct contact with surface water or groundwater;
    - The shredded tires are isolated from overburden materials by a protective membrane or liner to prevent intrusion and settling of overburden; and
    - An Iowa-licensed professional engineer designs and supervises the incorporation of shredded tires in beneficial uses of this manner.

4. Structural foundation drainage material used in a project as approved through a local building permit;

5. A bulking agent for composting operations at permitted composting facilities, with tire derived aggregates used to be no larger than 3 inches on any one side; and

6. Leachate drainage medium at a permitted municipal landfill, provided that the medium meets engineering and design requirements for the landfill's operating permit, pursuant to 567—Chapter 102.

Required Notifications and Approval for Shredded Tires

Prior IDNR notification and approval is required for any use of shredded tires in landfill applications.

Cut Tires

*Approved End Uses of Cut Tires**

***From Iowa Administrative Code – IAC 567-117**

1. Agricultural uses to hold down covers over hay, silage, and other agricultural commodities;
2. Traffic control devices for use in public roadway construction projects;
3. Portable surfaces manufactured from tire faces or tread;
4. Silt collection fences manufactured from tire faces or tread; and
5. Bagel-cut tires used for underturf water conservation and turf growth enhancement systems at golf courses.

All Beneficial Reuses of Cut Tires Must:*

***From Iowa Administrative Code – IAC 567-117**

1. Incorporate design and construction measures that prevent the retention and stagnation of water.
2. Minimize risks to pubic health and safety caused by the breeding of disease-carrying insects and rodents.

Required Notifications and Approval for Cut Tires

Prior IDNR notification and approval is required for any use of cut tires in landfill applications.

Other Beneficial Reuses of Tires*

***From Iowa Administrative Code – IAC 567-117**

1. The department has authority to approve or deny requests for beneficial use applications for whole, shredded, baled, or cut waste tires that are not specifically addressed in IAC Chapter 117.
2. Requests for other determinations must be made in writing to the department.
3. The department may request project descriptions and supporting scientific and engineering data to determine if a beneficial use request is warranted.
4. The department has 30 days to approve or deny a request

Primary Reasons a Beneficial Reuse Request May be Denied by the State of Iowa*

***From Iowa Administrative Code – IAC 567-117**

1. The requested beneficial use designation poses a risk to the environment or to the public health, welfare, and safety;
2. The requested beneficial use designation is determined to have the primary purpose as a land disposal mechanism, and any beneficial use would be incidental in nature; or
3. The requested beneficial use designation would not be in accordance with other applicable federal, state, or local laws, regulations, and ordinances.

Compliance with Local, State, and Federal Regulations*

***From Iowa Administrative Code – IAC 567-117**

Any proposed beneficial use project or application of whole, shredded, baled, or cut waste tires may require approval or permits from federal, state, and local agencies, under other laws, regulations, and ordinances, as applicable, including but not limited to the following:

- The Army Corps of Engineers, for projects involving navigable waterways and other waterways over which it has jurisdiction;
- Waste tire beneficial use applications involving placement on or within land or waters contained within a floodplain which require approval from the department’s floodplain management program, as specified in 567—Chapters 70 through 75; and
- Local building codes, zoning and land-use covenants, ordinances, and guidelines.

Tips for Submitting a Permit Amendment for a Tire Use Project:

1. Make request in writing on letterhead paper.
2. Reference the site name and permit number.
3. Be specific in what is being requested.
4. Provide graphics and visuals, etc., as necessary.
5. Provide a site map showing the location of the proposed project.
6. State how long the project will last.
7. State if there is required storage.
8. Provide justification and supportive documentation for the request.
9. May need to update any associated landfill plans, if approved, to reflect the changes.
10. Make sure project complies with all other local, state, and federal rules and procedures.

As with any amendment request, upfront communication between landfill staff, design engineers, and the Iowa DNR will help reduce confusion over project goals and assist to expedite the review process.

Appendix A:

Iowa Administrative Code 567-117

Appendix B:

Sample Specifications for Landfill Engineering Applications

Leachate Collection Layer Model Specifications

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Utilization of Tire Derived Aggregate (TDA) for:
   1. Landfill Leachate Collection Layer

1.02 DESCRIPTION OF WORK

A. Perform all duties required to complete the work shown in the Engineering Plans.

B. Prepare site for work and fill as specified in the Engineering Plans.

1.03 DEFINITIONS

A. Tire Derived Aggregate (TDA) – Pieces of processed tires that have a consistent shape and are generally between 25mm (1 inch) and 300mm (12 inches) in size.

1.04 SUBMITTALS

A. Submit as prescribed by Jurisdictional Engineer.

B. Samples, TDA: submit 25-pound samples of each type, if required.

C. Gradation reports for TDA, if required.

D. Results of Standard Proctor and In-Place Density Tests on TDA, if required.

E. Upon requests, the Contractor will provide Material Certifications to the Jurisdictional Engineer.

1.05 SUBSTITUTIONS

A. Use only materials conforming to these specifications unless permitted otherwise by Jurisdictional Engineer.

B. Obtain approval of Jurisdictional Engineer for all substitutions prior to use.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver only TDA that fully conforms to these specifications, or for which submittals have been provided to Jurisdictional Engineer and approved for use.

B. TDA transported in trucks/trailers that are free from dirt, oil, gas, organic matter, and other residue.

C. Store delivered TDA in locations that will not interfere with operations and minimize environmental damage.

D. Store TDA in compliance of Iowa Administrative Code IAC 567-117.6(4)

E. Grade and shape stockpiles for drainage and protect adjacent areas from runoff. Provide erosion control around stockpiles.

F. Remove unsuitable and excess TDA from the site.

1.07 SCHEDULING AND CONFLICTS

A. Construction Sequence:

1. Attend a preconstruction meeting if required by Jurisdictional Engineer.

2. Submit plan for construction sequence and schedule prior to commencing construction.

B. Conflict Avoidance:

1. Expose possible conflicts in advance of construction, such as utility lines and drainage structures. Contractor shall verify elevations and locations of each and verify clearance for proposed construction.

2. Notify Jurisdictional Engineer of conflicts discovered or changes needed to accommodate unknown or changed conditions.

1.08 SPECIAL REQUIREMENTS

A. **Stop Work:** Stop work and notify Jurisdictional Engineer immediately if contaminated soils, historical artifacts, or other environmental or historic items are encountered.

B. Conform to local, state, and federal requirements.

1.09 MEASUREMENT FOR PAYMENT

All measurements for payments will be made by the Jurisdictional Engineer or authorized representative.

A. **General:** Preparation, Placement, and Compaction shall be included in the costs in the unit bid for all structures, except as follows:

   1. **Unsuitable TDA:** Where TDA found unsuitable for use and cannot be made suitable in the opinion of Jurisdictional Engineer, Jurisdictional Engineer shall measure replacement TDA furnished by Contractor by cubic yards, furnished, transported, and properly installed. Payment shall be made at the unit bid price (per cubic yard or ton) or by change order.

B. TDA should be placed according to project plans and compacted as specified.

C. Weigh tickets showing tons of TDA for each load shall be kept to verify final amount delivered.

D. TDA pricing will be determined on a unit base price (per cubic yard or ton).

E. **Compaction Testing:** Shall be in accordance with the following:

   1. Contract documents shall indicate whether Jurisdiction or contractor shall be responsible for testing.

   2. If the contractor is responsible for testing, it shall be performed by an authorized independent testing lab hired by the contractor and shall be paid for on a lump sum basis.

   3. If the Jurisdiction is responsible for testing, the Jurisdiction shall assume costs of all tests required, except retesting resulting from failure of the initial tests. Pay request for testing shall indicate whether the test is initial or a retest.

   4. In all cases, the Contractor shall pay for retesting resulting from failure of initial tests.

PART 2 PRODUCTS

2.01 MATERIALS

A. Leachate Collection Layer TDA

1. TDA produced from passenger car and truck tires meeting Class I standards as provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270:

   Class I Fills: ***For use in applications in layers less than 1m (~3') thick.*** (From ASTM D6270)

   - Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
   - Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

B. Leachate Collection TDA is also subject to the following gradation:

1. 3" to 4" nominal in size

C. Unsuitable Material: Unsuitable material shall include TDA:

1. Not meeting Class I standards as provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270.
2. Containing dirt clods, loose wires, or coated in fines.
3. Exposed to excess oil, grease, gasoline, diesel fuel or other materials that may present a fire hazard.
4. Containing wood debris or fibrous organic matter.
5. Previously subjected to fire.

D. Replacement of Unsuitable Leachate Collection Layer Material

1. If the TDA is determined by the Jurisdictional Engineer to be unsuitable, furnish all necessary replacement TDA.
2. Remove and dispose of unsuitable TDA from the site.

E. Compressibility

1. Test in accordance with ASTM D 6270.

F. Hydraulic Conductivity (permeability)

1. Test in accordance with ASTM D 6270.
2. TDA layer must have a coefficient of permeability of 1×10^{-3} cm/sec (2.8 ft/day) or greater.

G. Shear Strength

1. Test in accordance with ASTM D 6270.

2.02 SOURCE QUALITY CONTROL

A. Producer to provide test results for the properties identified in Section 2.01.

PART 3 EXECUTION

3.01 EXAMINATION

A. TDA layer should not be applied until after inspection and approval of the underlayer.

B. Prepare appropriate subgrade as prescribed in Engineering Plan.

3.02 PREPARATION

A. Provide for proper protection of subgrade surfacing as necessary.

3.03 FILLING

A. Placement of TDA should occur in 12 inch lifts over the entire installation area. Steel wheeled/tracked equipment (bulldozer, compactor) may be utilized to compact each lift with an average of 4 to 6 passes.

B. Final compaction should utilize a smooth roller sheepsfoot.

C. Surface of final layer should be uniform and keyed firmly in place.

D. Final fill depth should be as specified in final Engineering Plan.

E. Protect existing facilities and landscaping features, or replace at Contractor's expense.

F. Protect bench marks, control points, and land survey monuments, or replace at Contractor's expense.

3.04 FIELD QUALITY CONTROL

A. TDA layer compacted thickness should be measured a minimum of one time per acre.

3.05 QUALITY ASSURANCE

A. Obtain samples from on-site stockpiles in accordance to ASTM D75.

B. Conduct gradation tests in accordance with ASTM D6270.

C. Sample and test TDA at a frequency of 1 test per 1000 cubic yards.

END OF SECTION

Landfill Gas Collection Layer Model Specifications

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Utilization of Tire Derived Aggregate (TDA) for:
   1. Landfill Gas Collection Layer

1.02 DESCRIPTION OF WORK

A. Perform all duties required to complete the work shown in the Engineering Plans.

B. Prepare site for work and fill as specified in the Engineering Plans.

1.03 DEFINITIONS

A. Tire Derived Aggregate (TDA) – Pieces of processed tires that have a consistent shape and are generally between 25mm (1 inch) and 300mm (12 Inches) in size.

1.04 SUBMITTALS

A. Submit under provisions of Division 1.

B. Samples, TDA: submit 25-pound samples of each type, if required.

C. Gradation reports for TDA, if required.

D. Results of Standard Proctor and In-Place Density Tests on TDA, if required.

E. Upon requests, the Contractor will provide Material Certifications to the Jurisdictional Engineer.

1.05 SUBSTITUTIONS

A. Use only materials conforming to these specifications unless permitted otherwise by Jurisdictional Engineer.

B. Obtain approval of Jurisdictional Engineer for all substitutions prior to use.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver only TDA that fully conforms to these specifications, or for which submittals have been provided to Jurisdictional Engineer and approved for use.

B. TDA transported in trucks/trailers that are free from dirt, oil, gas, organic matter, and other residue.

C. Store delivered TDA in locations that will not interfere with operations and minimize environmental damage.

D. Store TDA in compliance of Iowa Administrative Code IAC 567-117.6(4)

E. Grade and shape stockpiles for drainage and protect adjacent areas from runoff. Provide erosion control around stockpiles.

F. Remove unsuitable and excess TDA from the site.

1.07 SCHEDULING AND CONFLICTS

A. Construction Sequence:

1. Attend a preconstruction meeting if required by Jurisdictional Engineer.

2. Submit plan for construction sequence and schedule prior to commencing construction.

B. Conflict Avoidance:

1. Expose possible conflicts in advance of construction, such as utility lines and drainage structures. Contractor shall verify elevations and locations of each and verify clearance for proposed construction.

2. Notify Jurisdictional Engineer of conflicts discovered or changes needed to accommodate unknown or changed conditions.

1.08 SPECIAL REQUIREMENTS

A. **Stop Work:** Stop work and notify Jurisdictional Engineer immediately if contaminated soils, historical artifacts, or other environmental or historic items are encountered.

B. Conform to local, state, and federal requirements.

1.09 MEASUREMENT FOR PAYMENT

All measurements for payments will be made by the Jurisdictional Engineer or authorized representative.

A. **General:** Preparation, Placement, and Compaction shall be included in the costs in the unit bid for all structures, except as follows:

   1. **Unsuitable TDA:** Where TDA found unsuitable for use and cannot be made suitable in the opinion of Jurisdictional Engineer, Jurisdictional Engineer shall measure replacement TDA furnished by Contractor by cubic yards, furnished, transported, and properly installed. Payment shall be made at the unit bid price (per cubic yard or ton) or by change order.

B. TDA should be placed according to project plans and compacted as specified.

C. Weigh tickets showing tons of TDA for each load shall be kept to verify final amount delivered.

D. TDA pricing will be determined on a unit base price (per cubic yard or ton).

E. **Compaction Testing:** Shall be in accordance with the following:

   1. Contract documents shall indicate whether Jurisdiction or contractor shall be responsible for testing.

   2. If the contractor is responsible for testing, it shall be performed by an authorized independent testing lab hired by the contractor and shall be paid for on a lump sum basis.

   3. If the Jurisdiction is responsible for testing, the Jurisdiction shall assume costs of all tests required, except retesting resulting from failure of the initial tests. Pay request for testing shall indicate whether the test is initial or a retest.

   4. In all cases, the Contractor shall pay for retesting resulting from failure of initial tests.

PART 2 PRODUCTS

2.03 MATERIALS

A. Gas Collection Layer TDA

1. TDA produced from passenger car and truck tires meeting Class I standards as provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270:

Class I Fills: ***For use in applications in layers less than 1m (~3') thick***. (From ASTM D 6270)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

B. Gas Collection Layer TDA is also subject to the following gradation:

Sieve Size in. (MM)	Minimum Passing (% by weight)
12 (300)	100
6 (150)	95
3 (75)	50
#4 (4.75)	5

GeoSyntec Consultants, Inc., "Guidance Manual: Tire Shreds as Gas Collection Material at Municipal Solid Waste Landfills", California Integrated Waste Management Board web site, <http://www.ciwmb.ca.gov/Publications/default.asp?pubid=772>, April 15, 2005.

C. Unsuitable Material: Unsuitable material shall include TDA:

1. Not meeting Class I standards as provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270.
2. Containing dirt clods, loose wires, or coated in fines.
3. Exposed to excess oil, grease, gasoline, diesel fuel or other materials that may present a fire hazard.
4. Containing wood debris or fibrous organic matter.
5. Previously subjected to fire.

D. Replacement of Unsuitable Gas Collection Layer Material

1. If the TDA is determined by the Jurisdictional Engineer to be unsuitable, furnish all necessary replacement TDA.
2. Remove and dispose of unsuitable TDA from the site.

E. Compressibility

    1. Test in accordance with ASTM D 6270.

F. Hydraulic Conductivity (permeability)

    1. Test in accordance with ASTM D 6270.

G. Shear Strength

    1. Test in accordance with ASTM D 6270.

2.04 SOURCE QUALITY CONTROL

A. Producer to provide test results for the properties identified in Section 2.01.

PART 3 EXECUTION

3.03 EXAMINATION

A. TDA layer should not be applied until after inspection and approval of the underlayer.

B. Prepare appropriate subgrade as prescribed in Engineering Plan.

3.04 PREPARATION

A. Provide for proper protection of subgrade surfacing as necessary.

3.03 FILLING

A. Placement of TDA should occur in 12 inch lifts over the entire installation area. Steel wheeled/tracked equipment (bulldozer, compactor) may be utilized to compact each lift with an average of 4 to 6 passes.

B. Final compaction should utilize a smooth roller sheepsfoot.

C. Surface of final layer should be uniform and keyed firmly in place.

D. Final fill depth should be as specified in final Engineering Plan.

E. Protect existing facilities and landscaping features, or replace at Contractor's Expense.

F. Protect bench marks, control points, and land survey monuments, or replace at Contractor's expense.

3.04 FIELD QUALITY CONTROL

A. TDA layer compacted thickness should be measured a minimum of one time per acre.

3.05 QUALITY ASSURANCE

A. Obtain samples from on-site stockpiles in accordance to ASTM D75.

B. Conduct gradation tests in accordance with ASTM D6270.

C. Sample and test TDA at a frequency of 1 test per 1000 cubic yards.

END OF SECTION

Landfill Gas Control Trench Model Specifications

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Utilization of Tire Derived Aggregate (TDA) for:
   1. Landfill Gas Control Trench

1.02 DESCRIPTION OF WORK

A. Perform all duties required to complete the work shown in the Engineering Plans.

B. Prepare site for work, excavation, and fill as specified in the Engineering Plans.

1.03 DEFINITIONS

A. Tire Derived Aggregate (TDA) – Pieces of processed tires that have a consistent shape and are generally between 25mm (1 inch) and 300mm (12 Inches) in size.

1.04 SUBMITTALS

A. Submit under provisions of Division 1.

B. Samples, TDA: submit 25-pound samples of each type, if required.

C. Gradation reports for TDA, if required.

D. Results of Standard Proctor and In-Place Density Tests on TDA, if required.

E. Upon requests, the Contractor will provide Material Certifications to the Jurisdictional Engineer.

1.05 SUBSTITUTIONS

A. Use only materials conforming to these specifications unless permitted otherwise by Jurisdictional Engineer.

B. Obtain approval of Jurisdictional Engineer for all substitutions prior to use.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver only TDA that fully conforms to these specifications, or for which submittals have been provided to Jurisdictional Engineer and approved for use.

B. TDA transported in trucks/trailers that are free from dirt, oil, gas, organic matter, and other residue.

C. Store delivered TDA in locations that will not interfere with operations and minimize environmental damage.

D. Store TDA in compliance of Iowa Administrative Code IAC 567-117.6(4)

E. Grade and shape stockpiles for drainage and protect adjacent areas from runoff. Provide erosion control around stockpiles.

F. Remove unsuitable and excess TDA from the site.

1.07 SCHEDULING AND CONFLICTS

A. Construction Sequence:

1. Attend a preconstruction meeting if required by Jurisdictional Engineer.

2. Submit plan for construction sequence and schedule prior to commencing construction.

B. Conflict Avoidance:

1. Expose possible conflicts in advance of construction, such as utility lines and drainage structures. Contractor shall verify elevations and locations of each and verify clearance for proposed construction.

2. Notify Jurisdictional Engineer of conflicts discovered or changes needed to accommodate unknown or changed conditions.

1.08 SPECIAL REQUIREMENTS

A. **Stop Work:** Stop work and notify Jurisdictional Engineer immediately if contaminated soils, historical artifacts, or other environmental or historic items are encountered.

B. Conform to local, state, and federal requirements.

1.09 MEASUREMENT FOR PAYMENT

All measurements for payments will be made by the Jurisdictional Engineer or authorized representative.

A. **General:** Preparation, Placement, and Compaction shall be included in the costs in the unit bid for all structures, except as follows:

   1. **Unsuitable TDA:** Where TDA found unsuitable for use and cannot be made suitable in the opinion of Jurisdictional Engineer, Jurisdictional Engineer shall measure replacement TDA furnished by Contractor by cubic yards, furnished, transported, and properly installed. Payment shall be made at the unit bid price (per cubic yard or ton) by change order.

B. TDA should be placed according to project plans and compacted as specified.

C. Weigh tickets showing tons of TDA for each load shall be kept to verify final amount delivered.

D. TDA pricing will be determined on a unit base price (per cubic yard or ton).

E. **Compaction Testing:** Shall be in accordance with the following:

   1. Contract documents shall indicate whether Jurisdiction or contractor shall be responsible for testing.

   2. If the contractor is responsible for testing, it shall be performed by an authorized independent testing lab hired by the contractor and shall be paid for on a lump sum basis.

   3. If the Jurisdiction is responsible for testing, the Jurisdiction shall assume costs of all tests required, except retesting resulting from failure of the initial tests. Pay request for testing shall indicate whether the test is initial or a retest.

   4. In all cases, the Contractor shall pay for retesting resulting from failure of initial tests.

PART 2 PRODUCTS

2.05 MATERIALS

A. Gas Control Trench TDA

1. TDA produced from passenger car and truck tires meeting Class I standards as provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270:

Class I Fills: ***For use in applications in layers less than 1m (~3') thick***. (From ASTM D6270)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

B. Gas Control Trench TDA is also subject to the following gradation:

Sieve Size in. (MM)	Minimum Passing (% by weight)
12 (300)	100
6 (150)	95
3 (75)	50
#4 (4.75)	5

GeoSyntec Consultants, Inc., "Guidance Manual: Tire Shreds as Gas Collection Material at Municipal Solid Waste Landfills", California Integrated Waste Management Board web site, <http://www.ciwmb.ca.gov/Publications/default.asp?pubid=772>, April 15, 2005.

C. Unsuitable Material: Unsuitable material shall include TDA:

1. Not meeting Class I standards as provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270.
2. Containing dirt clods, loose wires, or coated in fines.
3. Exposed to excess oil, grease, gasoline, diesel fuel or other materials that may present a fire hazard.
4. Containing wood debris or fibrous organic matter.
5. Previously subjected to fire.

D. Replacement of Unsuitable Gas Control Trench TDA

1. If the TDA is determined by the Jurisdictional Engineer to be unsuitable, furnish all necessary replacement TDA.
2. Remove and dispose of unsuitable TDA from the site.

E. Compressibility

1. Test in accordance with ASTM D 6270.

F. Hydraulic Conductivity (permeability)

1. Test in accordance with ASTM D 6270.

2.06 SOURCE QUALITY CONTROL

A. Producer to provide test results for the properties identified in Section 2.01.

PART 3 EXECUTION

3.05 EXAMINATION

A. TDA layer should not be applied until after inspection and approval of the underlayer.

B. Prepare appropriate subgrade as prescribed in Engineering Plan.

3.06 PREPARATION

A. Provide for proper protection of subgrade surfacing as necessary.

3.03 FILLING

A. Placement of TDA should occur in 12 inch lifts over the entire installation area. Steel wheeled/tracked equipment (bulldozer, compactor) may be utilized to compact each lift with an average of 4 to 6 passes.

B. Final compaction should utilize a smooth roller sheepsfoot.

C. Surface of final layer should be uniform and keyed firmly in place.

D. Final fill depth should be as specified in final Engineering Plan.

E. Protect existing facilities and landscaping features, or replace as shown on the plans.

F. Protect bench marks, control points, and land survey monuments, or replace at Contractor's expense.

3.04 FIELD QUALITY CONTROL

A. TDA layer compacted thickness should be measured a minimum of one time per 500 linear feet.

3.05 QUALITY ASSURANCE

A. Obtain samples from on-site stockpiles in accordance to ASTM D75.

B. Conduct gradation tests in accordance with ASTM D6270.

C. Sample and test TDA at a frequency of 1 test per 1000 cubic yards.

END OF SECTION

Landfill Operations Layer Model Specifications

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Utilization of Tire Derived Aggregate (TDA) for:
   1. Landfill Operations Layer

1.02 DESCRIPTION OF WORK

A. Perform all duties required to complete the work shown in the Engineering Plans.

B. Prepare site for work, and fill as specified in the Engineering Plans.

1.03 DEFINITIONS

A. Landfill Operations Layer – Separates waste from and provides protection to the underlying landfill containment system. The layer is typically located between a landfill's initial lift of solid waste and the leachate collection layer.

B. Tire Derived Aggregate (TDA) – Pieces of processed tires that have a consistent shape and are generally between 25mm (1 inch) and 300mm (12 Inches) in size.

1.04 SUBMITTALS

A. Submit under provisions of Division 1.

B. Samples, TDA: submit 25-pound samples of each type, if required.

C. Gradation reports for TDA, if required.

D. Results of Standard Proctor and In-Place Density Tests on TDA, if required.

E. Upon requests, the Contractor will provide Material Certifications to the Jurisdictional Engineer.

1.05 SUBSTITUTIONS

A. Use only materials conforming to these specifications unless permitted otherwise by Jurisdictional Engineer.

B. Obtain approval of Jurisdictional Engineer for all substitutions prior to use.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver only TDA that fully conforms to these specifications, or for which submittals have been provided to Jurisdictional Engineer and approved for use.

B. TDA transported in trucks/trailers that are free from dirt, oil, gas, organic matter, and other residue.

C. Store delivered TDA in locations that will not interfere with operations and minimize environmental damage.

D. Store TDA in compliance of Iowa Administrative Code IAC 567-117.6(4)

E. Grade and shape stockpiles for drainage and protect adjacent areas from runoff. Provide erosion control around stockpiles.

F. Remove unsuitable and excess TDA from the site.

1.07 SCHEDULING AND CONFLICTS

A. Construction Sequence:

1. Attend a preconstruction meeting if required by Jurisdictional Engineer.
2. Submit plan for construction sequence and schedule prior to commencing construction.

B. Conflict Avoidance:

1. Expose possible conflicts in advance of construction, such as utility lines and drainage structures. Contractor shall verify elevations and locations of each and verify clearance for proposed construction.
2. Notify Jurisdictional Engineer of conflicts discovered or changes needed to accommodate unknown or changed conditions.

1.08 SPECIAL REQUIREMENTS

A. **Stop Work:** Stop work and notify Jurisdictional Engineer immediately if contaminated soils, historical artifacts, or other environmental or historic items are encountered.

B. Conform to local, state, and federal requirements.

1.09 MEASUREMENT FOR PAYMENT

All measurements for payments will be made by the Jurisdictional Engineer or authorized representative.

A. **General:** Preparation, Placement, and Compaction shall be included in the costs in the unit bid for all structures, except as follows:

1. **Unsuitable TDA:** Where TDA found unsuitable for use and cannot be made suitable in the opinion of Jurisdictional Engineer, Jurisdictional Engineer shall measure replacement TDA furnished by Contractor by cubic yards, furnished, transported, and properly installed. Payment shall be made at the unit bid price (per cubic yard or ton) or by change order.

B. TDA should be placed according to project plans and compacted as specified.

C. Weigh tickets showing tons of TDA for each load shall be kept to verify final amount delivered.

D. TDA pricing will be determined on a unit base price (per cubic yard or ton).

E. **Compaction Testing:** Shall be in accordance with the following:

1. Contract documents shall indicate whether Jurisdiction or contractor shall be responsible for testing.

2. If the contractor is responsible for testing, it shall be performed by an authorized independent testing lab hired by the contractor and shall be paid for on a lump sum basis.

3. If the Jurisdiction is responsible for testing, the Jurisdiction shall assume costs of all tests required, except retesting resulting from failure of the initial tests. Pay request for testing shall indicate whether the test is initial or a retest.

4. In all cases, the Contractor shall pay for retesting resulting from failure of initial tests.

PART 2 PRODUCTS

2.07 MATERIALS

A. Landfill Operations Layer TDA

1. TDA produced from passenger car and truck tires meeting Class I standards as provided by American Society for Testing and Materials (ASTM) International ASTM D 6270:

Class I Fills: ***For use in applications in layers less than 1m (~3') thick.*** (From ASTM D6270)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

B. Operations layer TDA is also subject to the following gradation:

Sieve Size[2] in. (MM)	Minimum Passing (% by weight)
18 (450)	100
12 (300)	95
6 (150)	75

2 Indicates square mesh size

GeoSyntec Consultants, Inc., "Guidance Manual: Tire Shreds as Operations Layer Material at Municipal Solid Waste Landfills", California Integrated Waste Management Board web site, <http://www.ciwmb.ca.gov/Publications/default.asp?pubid=773>, April 15, 2005.

C. Unsuitable Material: Unsuitable material shall include TDA:

1. Not meeting Class I standards as provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270.
2. Containing dirt clods, loose wires, or coated in fines.
3. Exposed to excess oil, grease, gasoline, diesel fuel or other materials that may present a fire hazard.
4. Containing wood debris or fibrous organic matter.
5. Previously subjected to fire.

D. Replacement of Unsuitable Operations Layer Material

1. If the TDA is determined by the Jurisdictional Engineer to be unsuitable, furnish all necessary replacement TDA.

2. Remove and dispose of unsuitable TDA from the site.

E. Compressibility

1. Test in accordance with ASTM D 6270.

F. Hydraulic Conductivity (permeability)

1. Test in accordance with ASTM D 6270.

2.08 SOURCE QUALITY CONTROL

A. Producer to provide test results for the properties identified in Section 2.01.

PART 3 EXECUTION

3.07 EXAMINATION

A. TDA layer should not be applied until after inspection and approval of the underlayer.

B. Prepare appropriate subgrade as prescribed in Engineering Plan.

3.08 PREPARATION

A. Provide for proper protection of subgrade surfacing as necessary.

3.03 FILLING

A. Placement of TDA should occur in 12 inch lifts over the entire installation area. Steel wheeled/tracked equipment (bulldozer, compactor) may be utilized to compact each lift with an average of 4 to 6 passes.

B. Surface of final layer should be uniform and keyed firmly in place.

C. Final fill depth should be as specified in final engineering plan.

D. Protect existing facilities and landscaping features, or replace as shown on the plans.

E. Protect bench marks, control points, and land survey monuments, or replace at Contractor's expense.

3.04 FIELD QUALITY CONTROL

A. TDA layer compacted thickness should be measured a minimum of one time per 500 linear feet.

3.05 QUALITY ASSURANCE

A. Obtain samples from on-site stockpiles in accordance to ASTM D75.

B. Conduct gradation tests in accordance with ASTM D6270.

C. Sample and test TDA at a frequency of 1 test per 1000 cubic yards.

END OF SECTION

Landfill Road Base Model Specifications

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Utilization of Tire Derived Aggregate (TDA) for:
   1. Landfill Road Base

1.02 DESCRIPTION OF WORK

A. Perform all duties required to complete the work shown in the Engineering Plans.

B. Prepare site for work, and fill as specified in the Engineering Plans.

1.03 DEFINITIONS

A. Tire Derived Aggregate (TDA) – Pieces of processed tires that have a consistent shape and are generally between 25mm (1 inch) and 300mm (12 Inches) in size.

1.04 SUBMITTALS

A. Submit under provisions of Division 1.

B. Samples, TDA: submit 25-pound samples of each type, if required.

C. Gradation reports for TDA, if required.

D. Results of Standard Proctor and In-Place Density Tests on TDA, if required.

E. Upon requests, the Contractor will provide Material Certifications to the Jurisdictional Engineer.

1.05 SUBSTITUTIONS

A. Use only materials conforming to these specifications unless permitted otherwise by Jurisdictional Engineer.

B. Obtain approval of Jurisdictional Engineer for all substitutions prior to use.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver only TDA that fully conforms to these specifications, or for which submittals have been provided to Jurisdictional Engineer and approved for use.

B. TDA transported in trucks/trailers that are free from dirt, oil, gas, organic matter, and other residue.

C. Store delivered TDA in locations that will not interfere with operations and minimize environmental damage.

D. Store TDA in compliance of Iowa Administrative Code IAC 567-117.6(4)

E. Grade and shape stockpiles for drainage and protect adjacent areas from runoff. Provide erosion control around stockpiles.

F. Remove unsuitable and excess TDA from the site.

1.07 SCHEDULING AND CONFLICTS

A. Construction Sequence:

1. Attend a preconstruction meeting if required by Jurisdictional Engineer.

2. Submit plan for construction sequence and schedule prior to commencing construction.

B. Conflict Avoidance:

1. Expose possible conflicts in advance of construction, such as utility lines and drainage structures. Contractor shall verify elevations and locations of each and verify clearance for proposed construction.

2. Notify Jurisdictional Engineer of conflicts discovered or changes needed to accommodate unknown or changed conditions.

1.08 SPECIAL REQUIREMENTS

A. **Stop Work:** Stop work and notify Jurisdictional Engineer immediately if contaminated soils, historical artifacts, or other environmental or historic items are encountered.

B. Conform to local, state, and federal requirements.

1.09 MEASUREMENT FOR PAYMENT

All measurements for payments will be made by the Jurisdictional Engineer or authorized representative.

A. **General:** Preparation, Placement, and Compaction shall be included in the costs in the unit bid for all structures, except as follows:

   1. **Unsuitable TDA:** Where TDA found unsuitable for use and cannot be made suitable in the opinion of Jurisdictional Engineer, Jurisdictional Engineer shall measure replacement TDA furnished by Contractor by cubic yards, furnished, transported, and properly installed. Payment shall be made at the unit bid price (per cubic yard or ton) or by change order.

B. TDA should be placed according to project plans and compacted as specified.

C. Weigh tickets showing tons of TDA for each load shall be kept to verify final amount delivered.

D. TDA pricing will be determined on a unit base price (per cubic yard or ton).

E. **Compaction Testing:** Shall be in accordance with the following:

   1. Contract documents shall indicate whether Jurisdiction or contractor shall be responsible for testing.

   2. If the contractor is responsible for testing, it shall be performed by an authorized independent testing lab hired by the contractor and shall be paid for on a lump sum basis.

   3. If the Jurisdiction is responsible for testing, the Jurisdiction shall assume costs of all tests required, except retesting resulting from failure of the initial tests. Pay request for testing shall indicate whether the test is initial or a retest.

   4. In all cases, the Contractor shall pay for retesting resulting from failure of initial tests.

PART 2 PRODUCTS

2.09 MATERIALS

A. Road Base TDA

   1. TDA produced from passenger car and truck tires meeting Class I or Class II standards *(depending on engineering specifications*) as

provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270:

Class I Fills: ***For use in applications in layers less than 1m (~3') thick**.* (From ASTM D6270)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

Class II Fills: (TDA placed in layers ranging from 1m (~3') to 3m (~10') thick.)

- Have a maximum of 25% (by weight) passing the 38 mm (1.5") sieve.
- Have a maximum of 1% (by weight) passing the 4.75 mm (~.19") sieve.
- Free from fragments of wood, wood chips, and other fibrous organic matter.
- Less than 1% (by weight) of metal fragments not at least partially encased in rubber.
- Metal fragments partially encased in rubber shall protrude no more than 25 mm (~1") from the cut edge of the tire derived aggregate on 75% of the pieces and nor more than 50 mm (~2") on 100% of the pieces.
- Projects should be constructed in a way that minimizes infiltration of water and air.
- No direct contact between tire derived aggregates and soil containing organic material (i.e. topsoil)
- Drainage features located at the bottom of the fill that could provide free access to air should be avoided.

B. Unsuitable Material: Unsuitable material shall include TDA:

1. Not meeting Class I or Class II standards as provided by American Society for Testing and Materials (ASTM) International Standard ASTM D 6270.
2. Containing dirt clods, loose wires, or coated in fines.
3. Exposed to excess oil, grease, gasoline, diesel fuel or other materials that may present a fire hazard.
4. Containing wood debris or fibrous organic matter.

5. Previously subjected to fire.

C. Replacement of Unsuitable Landfill Road Base TDA Material

1. If the TDA is determined by the Jurisdictional Engineer to be unsuitable, furnish all necessary replacement TDA.

2. Remove and dispose of unsuitable TDA from the site.

D. Compressibility

1. Test in accordance with ASTM D 6270.

E. Hydraulic Conductivity (permeability)

1. Test in accordance with ASTM D 6270.

2.10 SOURCE QUALITY CONTROL

A. Producer to provide test results for the properties identified in Section 2.01.

PART 3 EXECUTION

3.09 EXAMINATION

A. TDA layer should not be applied until after inspection and approval of the underlayer.

B. Prepare appropriate subgrade as prescribed in Engineering Plan.

3.10 PREPARATION

A. Provide for proper protection of subgrade surfacing as necessary.

3.03 FILLING

A. Placement of TDA should occur in 12 inch lifts over the entire installation area. Steel wheeled/tracked equipment (bulldozer, compactor) may be utilized to compact each lift with an average of 4 to 6 passes.

B. Final compaction should utilize a smooth roller sheepsfoot.

C. Surface of final layer should be uniform and keyed firmly in place.

D. Final fill depth should be as specified in final Engineering Plan.

E. Protect existing facilities and landscaping features, or replace as shown on the plans.

F. Protect bench marks, control points, and land survey monuments, or replace at Contractor's expense.

3.04 FIELD QUALITY CONTROL

A. TDA layer compacted thickness should be measured a minimum of one time per 500 linear feet.

3.05 QUALITY ASSURANCE

A. Obtain samples from on-site stockpiles in accordance to ASTM D75.

B. Conduct gradation tests in accordance with ASTM D6270.

C. Sample and test TDA at a frequency of 1 test per 1000 cubic yards.

END OF SECTION

Appendix C:

Sources of Tire Derived Aggregate

Tire Derived Aggregate (TDA) Procurement

Pricing strategies by tire processors can vary by facility and season and can be dependant on variables that include:

1. Specification requirements for TDA.
    - (Smaller sizes generally require more time/labor to produce)
    - (TDA with less exposed or no wire is generally more expensive)
2. Quantity of TDA being purchased.
3. Distance from processing facility to project site.
4. Demand from other market outlets.

Tire Derived Aggregate (TDA) Size Specifications

Class I Fills: ***For use in applications in layers less than 1m (~3') thick***. (4)

- Have a maximum of 50% (by weight) passing the 38 mm (~1.5") sieve.
- Have a maximum of 5% (by weight) passing the 4.75 mm (~.19") sieve.

Class II Fills: ***For use in applications in layers ranging from 1m (~3') to 3m (~10') thick.*** (4)

- Have a maximum of 25% (by weight) passing the 38 mm (1.5") sieve.
- Have a maximum of 1% (by weight) passing the 4.75 mm (~.19") sieve.
- Free from fragments of wood, wood chips, and other fibrous organic matter.
- Less than 1% (by weight) of metal fragments not at least partially encased in rubber.
- Metal fragments partially encased in rubber shall protrude no more than 25 mm (~1") from the cut edge of the tire derived aggregate on 75% of the pieces and nor more than 50 mm (~2") on 100% of the pieces.
- Projects should be constructed in a way that reduces infiltration of water and air.
- No direct contact between tire derived aggregates and soil containing organic material (i.e. topsoil).
- Drainage features located at the bottom of the fill that could provide free access to air should be avoided.

For many engineered landfill applications, the Iowa DNR will currently only approve the use of TDA in a 3” to 4” nominal size – unless engineering documentation is provided to substantiate a viable alternative design. (23)

Tire Derived Aggregate (TDA) Quantity Specifications

When ordering TDA, remember that it is typically lighter in weight than aggregate, sand, or soil and that, generally, a ton of TDA will cover a larger area than those conventional aggregates.

The average compacted density of TDA ranges from 40 lb/ft^3 to 50 lb/ft^3 and is 1/3 to 1/2 that of typical soils. (5)

Typical non compacted dry densities of 3” to 4” nominal TDA in Iowa have been reported to be between 24 lb/ft^3 and 28 lb/ft^3. (24)

Table 10, **Comparison of Fill Material Weights and Volumes**, shows that TDA has a non-compacted dry volume that is 1/3 to ¼ that of typical sand and gravel fills. This volume difference can result in materials and transportation savings.

Table 10: Comparison of Fill Material Weights and Volumes

Sand or Gravel	TDA*
1 TON = ~.74 YD^3	1 TON = ~2.8 YD^3

*Based on average dry density of 26 lb/ft^3 (24)

Example: A typical 12” thick landfill gas collection layer could require:

Approximately 2181 tons of sand or gravel

or

Approximately 577 tons of TDA

Permitted Waste Tire Processing Facilities in Iowa*

Facility Name	Facility Type	Products
D&B Salvage 4423 140th Street **Correctionville, IA** 51016 (712) 384-2703 (712) 253-7326 *Provides shredding services for final disposal* IDNR Permit #97-WMT-02-04P-PRT	**Mobile Processor**	Provide shredding services for final disposal.
Denis Gailey *1601 230th Street* **Moorland, IA** 50566 (515) 549-3390 *Provides shredding services for final disposal* IDNR Permit #94-WMT-03-05P-PRT	**Mobile Processor**	Provide shredding services for final disposal.
Greenman Technologies of Iowa 1914 E. Euclid Ave. **Des Moines, IA** 50321 (515) 262-4900 *Produces tire-derived fuel (TDF), shreds for civil engineering projects and crumb rubber* IDNR Permit #77-WTM-01-96P-PRT	**Processor**	Produce Tire-derived fuel, shreds for civil engineering projects and crumb rubber.
Koster Grinding, Inc. P.O. Box 194, 17995 Iris Ave. **Carroll, IA** 51401 (800) 798-5421 *Provides shredding services for final disposal* *and civil engineering projects* IDNR Permit #14-WTM-02-04P – PRT	**Mobile Processor**	Provide shredding services for final disposal and civil engineering projects. Produce a 3” shred and have grinding capacity of 8 tons/hour.
Lilleholm Tire Recycling 2075 290th St. **Denison, IA** 51442 (712) 263-3310 *Misc. erosion control and civil engineering products.* IDNR Permit #24-WTM-01-00P-PRT	**Processor**	Produce miscellaneous erosion control and civil engineering products.
Tire Environmental Services, Inc. 1602 Musser St. **Muscatine, IA** 52761 (563) 288-1963 *Produces tire-derived fuel (TDF), shreds for civil engineering projects, and various other markets* IDNR Permit #70-WTM-01-99P-PRT	**Processor**	Primarily produce tire derived fuel and landscape mulch products. Permitted to produce up to a 2” shred, but are capable of producing a 4-6” shred.

* Permit list obtained from IDNR website as of 5-9-05

* This list may not represent all waste tire processors in Iowa.

* http://www.iowadnr.com/waste/recycling/tires/files/storagelisting.pdf

Permitted Waste Tire Processing Facilities in Illinois*

Facility Name	Facility Type	Products
Lakin General Contact: Dick Gust 1323 W. Cortland Chicago, IL 60614 773/871-6360	**Processor**	
GreenMan Technologies Contact: Stan Williams 1914 E. Euclid Des Moines, IA 50313 515/262-4900	**Processor**	Produce Tire-derived fuel, shreds for civil engineering projects and crumb rubber.
New Heights Recovery Illinois, LLC Contact: Bob Garcia #6 Coulter Rd. Dupo, IL 62239 618/286-4545	**Processor**	
Metro Industries Tire Processing Inc. Alice & Herb Wright 1834 Minnesota Ave. Mulberry Grove, Illinois 62262 618/326-7401 (office) or 618/326-7817 (plant)	**Processor**	
Tire Shredders Unlimited Contact: Norvill Brown 1845 West Square High Ridge, MO 63049 636/677-8471	**Processor**	
Tire Shredders Unlimited Contact: Brent Walters 1822 N. Lincoln Parkway Lincoln, IL 62656 217/735-4995	**Processor**	
Tire Grinders Transporters, Inc. Contact: Jim Huizinga 175 South Des Plaines St. Joliet, IL 60436 815/722-7100	**Processor**	Mainly produce a 2" nominal size, but can vary size depending on need. Also produce crumb product.
Shred-All Recycling Systems Contact: Daniel Morales 1234 W. 43rd Street Chicago, IL 60609 773/523-5405	**Processor**	

* Permit list obtained from Illinois EPA website as of 5-9-05

* This list may not represent all waste tire processors in Illinois.

* http://www.epa.state.il.us/land/tires/used-tire-processors.html

Permitted Waste Tire Processing Facilities in Missouri*

Facility Name	Facility Type	Products
Alternative Fuel Source, Inc. 6839 Main St. P.O. Box 467 Odessa, MO 64076 (816) 230-5475 (800) 467-7057 WT Site Permit # 11107001 WT Processing Facility Permit # 09107001	**Processor**	Produce Tire-Derived Fuel
Beck's Tire Service 4950 Stilwell Street Kansas City, MO 64210 (816) 241-1155 or (800) 444-8159 WT Site Permit #11095001 WT Processing Facility Permit #09095001 www.planetuff.com	**Processor**	Sorting tires for resale/reuse
City of St. Joseph Sanitary Landfill 1100 Frederick Ave. St. Joseph, MO 64501 (816) 253-9025 WT Processing Facility Permit #09021001	**Processor**	Cutting tires for disposal
Missouri Vocational Enterprises P.O. Box 236 Jefferson City, MO 65102 (573) 751-6663 WT Site Permit #1105101 WT Processing Facility Permit #09051001	**Closed to the public**	Tire-Derived Fuel
City of Rolla Sanitation Department 2141 Old St. James Road Rolla, MO 65402 (573) 364-6693 WT Processing Facility Permit #09161001	**Processor**	Cutting tires for disposal
Don's Welding and Waste Tire Removal 5117 South 240th Road Halfway, MO 65663 (417) 267-7708 Mobile WT Proc. Fac. Permit #09167001	**Mobile Processor**	Cutting tires for disposal
EnTire Recycling, Inc. 13974 US Hwy 136 Rock Port, MO 64482 (660) 744-2252 (877) 209-7345 WT Processing Facility Permit #09005001 www.entirerecycling.com	**Processor**	Produce a 2" shred and crumb rubber.
Plaza Tire Service 2149 William St. Cape Girardeau, MO 63703 (573) 334-5036 WT Processing Facility Permit #09031001	**Closed to the public**	Cutting their own tires for disposal
Pemiscot County Transfer Station Route "Z" and U.S. Highway 412 West Hayti, MO 63851 (573) 359-1084 WT Processing Facility Permit #09155001	**Processor**	Cutting tires for disposal

Dash Recycled Rubber, Inc. 612 Blees Industrial Drive P.O. Box 126 Macon, MO 63552 (660) 385-7156 WT Site Permit # 11121003 WT Processing Facility Permit # 09121003	**Processor**	Crumb Rubber/Playground Material
Tire Shredders Unlimited P.O. Box 1485 High Ridge, MO 63049 (636) 677-8471 WT Site Permit #1109901 WT Processing Facility Permit #09099001 www.tireshred.com	**Processor**	Tire-Derived Fuel
TRI-RINSE, Inc. P.O. Box 15191 St. Louis, MO 63110 (314) 647-8338 Mobile WT Proc. Fac. Permit #09189001	**Closed to the public**	Illegal Tire Dump Cleanups
Waste Tire Transportation Services, LLC 55 NE Highway 69 Claycomo, MO 64119 (816) 616-9810 Mobile WT Proc. Fac. Permit #09047001	**Mobile Processor**	Cutting tires for disposal
The City of West Plains Solid Waste Transfer Station 1851 Good Hard Drive West Plains, MO 65775 (417) 255-2330 WT Processing Facility Permit #09091001	**Processor**	Cutting tires for disposal

* Permit list obtained from Missouri DNR website as of 5-9-05

* This list may not represent all waste tire processors in Missouri.

* http://www.dnr.mo.gov/alpd/swmp/tires/tireprocessors.htm

Permitted Waste Tire Processing Facilities in Minnesota*

Facility Name	Facility Type	Products
GreenMan Technologies of Minnesota 12498 Wyoming Avenue Savage, MN (612) 894-5280	Processor	Produces Tire-derived fuel, shreds for civil engineering projects and crumb rubber.
Monitor Tire Disposal 130 Maine St., Box 300 St. Martin, Minnesota 56376 Ph. (320) 548-3496 Fax (320) 548-3515 http://www.monitortiredisposal.com e-mail: monitor@meltel.net	Processor	Produce a 1' -2" TDA for Tire derived fuel and 3" to 5" and 5" to 8" chip mixes for engineering projects.
Tire Depot 1813 25th St S Moorhead, MN 56560 Phone: (218) 233-7417 Fax: (218) 233-7698	Processor	Produce a .25" TDA for animal bedding and smaller mesh mixes for animal arena surfacing and playground cover.
First State Tire Recycling East Bethel, MN (763) 757-0544	Processor	Produce TDA for a variety of civil projects.

* Permit list obtained from Minnesota Pollution Control website as of 5-9-05

* This list may not represent all waste tire processors in Minnesota.

* http://www.pca.state.mn.us/waste/pubs/w5-01.pdf

Permitted Waste Tire Processing Facilities in South Dakota*

Facility Name	Facility Type	Products
New Deal Tire, Inc. 117 West Highway 12 Groton, SD 57445 (605) 397-TIRE	**Processor**	Produce 1” chip for tire derived fuel.
Greenman Technologies of Minnesota, Inc. 12498 Wyoming Avenue Savage, MN 55378 Phone: (952) 894-5280 Fax: (952) 894-5061	**Processor**	Produce Tire-derived fuel, shreds for civil engineering projects and crumb rubber.
Waste-Not Recycling 2928 37th St NW Mandan, ND 58554-1315 Phone: (701) 663-3370 Fax: (701) 222-8945	**Processor**	
Butler County Landfill 3588 R Road David City, NE 68632 Phone: (402) 367-4662 Contact: Kelly Danielson	**Processor**	

* Permit list obtained from the South Dakota Department of Environment and Natural Resources website as of 5-9-05

* This list may not represent all waste tire processors in South Dakota.

* http://www.state.sd.us/denr/DES/wastemgn/recycling/tires.htm

Waste Tire Processing Facilities in Nebraska*

Facility Name	Facility Type	Products
Butler County Landfill 3599 R Road PO Box 126 David City, NE 68632 (402) 367-4662	**Processor**	
Champlin Tire Recycling Inc. P.O. Box 445 Concordia KS 66901 (800) 295-3345	**Processor**	Capable of producing a variety of TDF, including 3' to 4" nominal. Also have a mobile shredder.
EnTire Recycling 13974 US Highway 136 Rockport MO 64482 (660) 744-2252	**Processor**	
Spectracom, Inc. DBA River City Recycling 6404 S 60th St. Omaha NE 68117 (402) 734-9766	**Processor**	

* Processor identified through the Nebraska Department of Environmental Quality

* This list may not represent all waste tire processors in Nebraska.

* http://www.deq.state.ne.us/IntList.nsf/pages/scraptire

Waste Tire Processing Facilities in Wisconsin*

Facility Name	Facility Type	Products
Auburndale Tire Recycling Center 10453 S. George Ave... PO BOX 137 Auburndale, WI 54412 (715) 652-3622 FAX: (715) 652-6372 E-MAIL: arc@tznet.com http://www.auburndalerecycling.com/	**Processor**	
Greenman Technologies of Wisconsin 7595 Otten Ln Kewaskum, WI (262) 338-3352	**Processor**	Produce Tire-derived fuel, shreds for civil engineering projects and crumb rubber.

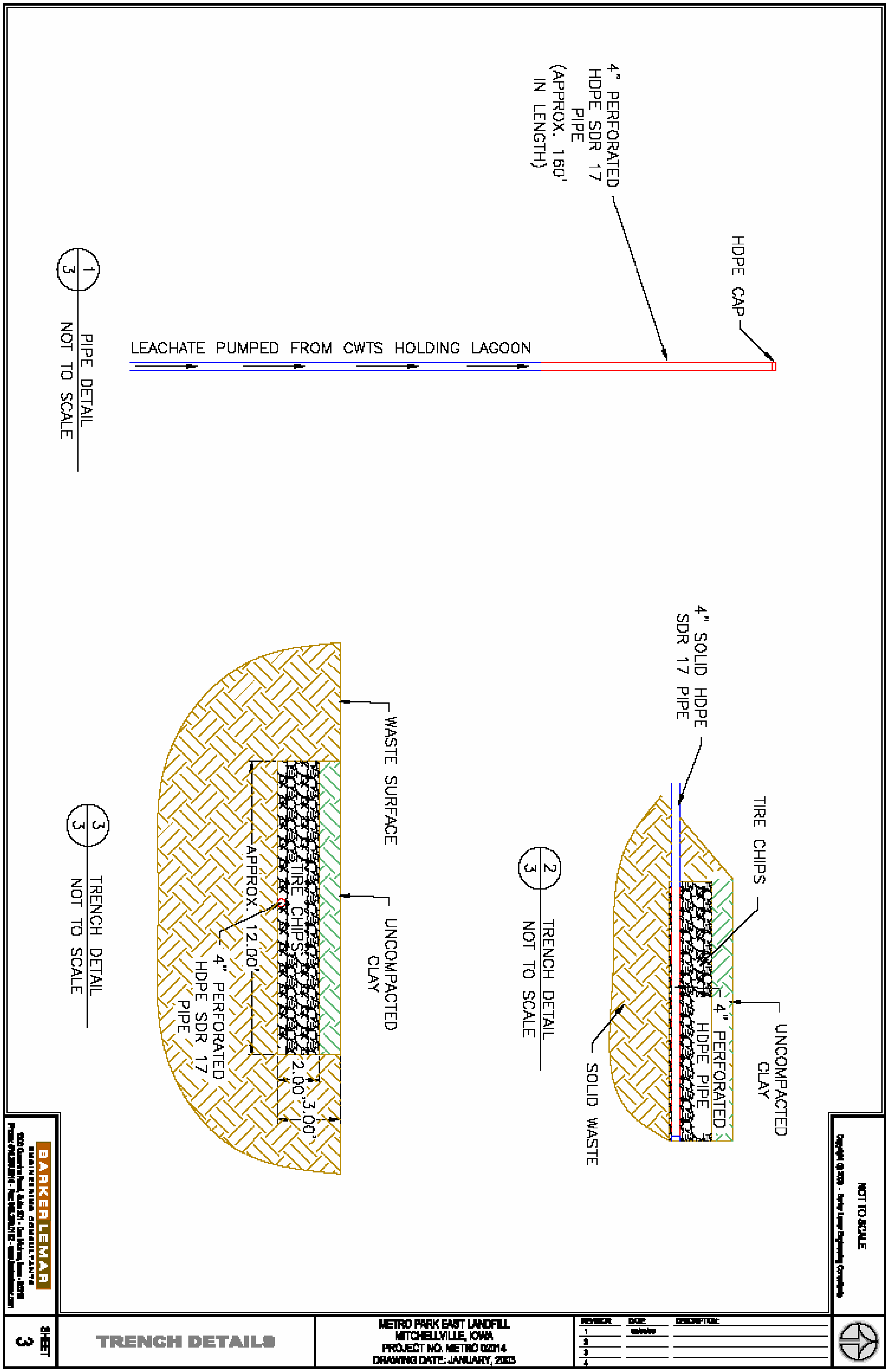
* Processors identified through the Nebraska Department of Environmental Quality

* This list may not represent all waste tire processors in Wisconsin.

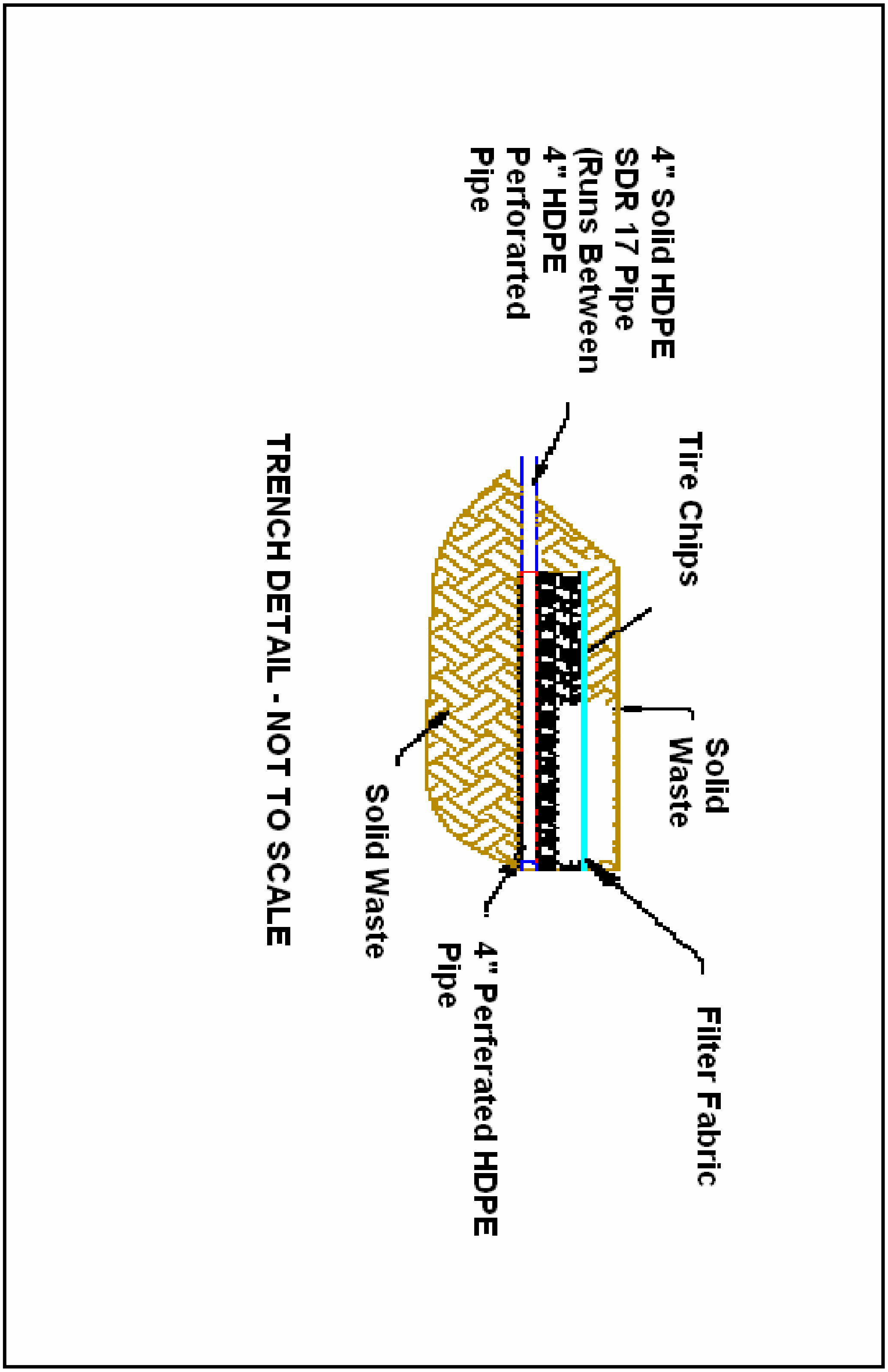
Appendix D:

Case Study Supplements

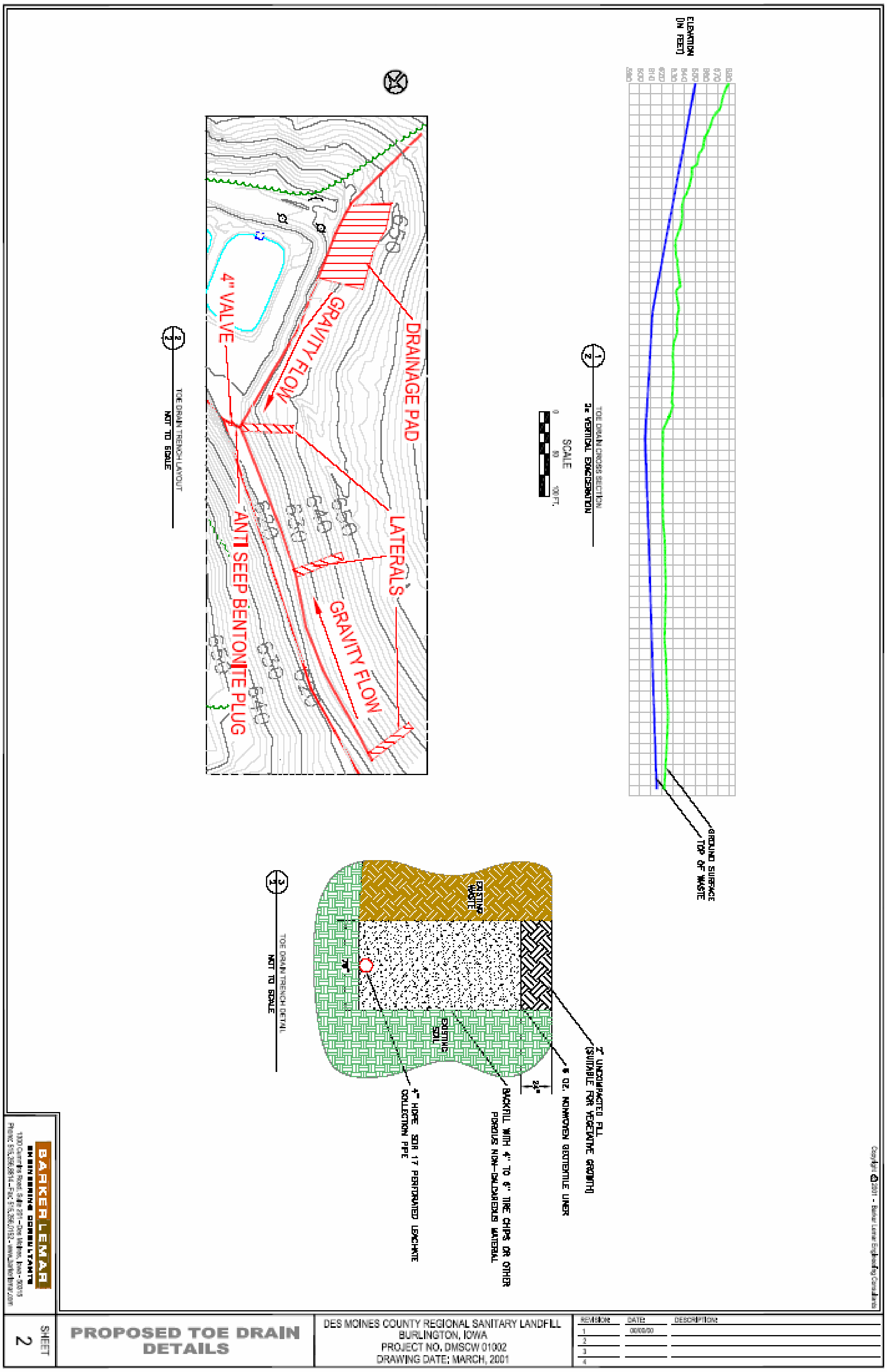
Case Study Supplement #1



Case Study Supplement #2



Case Study Supplement #3



Appendix E:

Works Cited
and
Additional Resources List

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<http://www.egr.msu.edu/cee/research/environmental/PROJ_FSTLRB.shtml>

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Engineered Tire Structures, Inc.
http://www.ecoflex.com.au

Iowa Department of Natural Resources
http://www.iowadnr.com/waste/recycling/tires/index.html

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http://www.scraptirenews.com/

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